Airfield Research Group Ltd

ARG Research Note No.57: Hatfield Wind Tunnels

Paul Francis – October 2016

Contents

Front cover: Exterior view of the fan section of the 15ft tunnel (V/STOL tunnel) 1990

I am very grateful to Robin Webb, the former head of department, who gave me a considerable amount of help and advice.

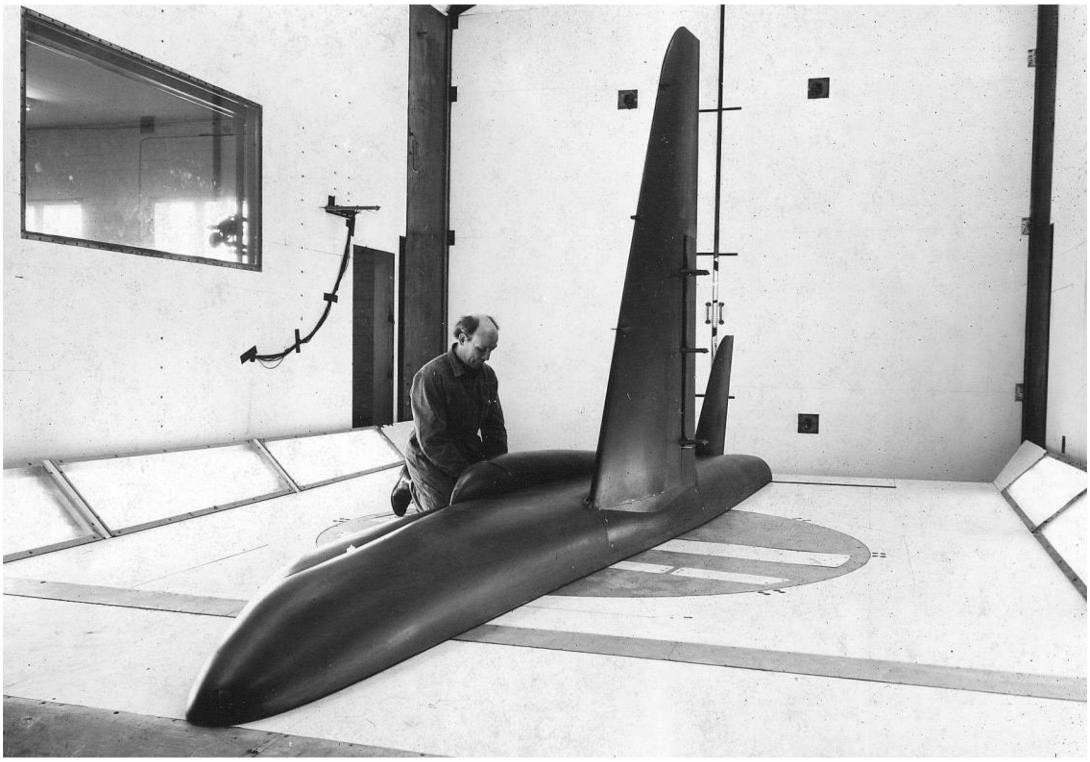

Plate 2: 1/2 scale half model of the HS 1182 in the V/STOL tunnel working section seen in February 1970. The model appears in its low wing configuration while another version of the same model had a high wing arrangement, the flap could also be set at different angles. Other versions included different engine blisters and with undercarriage down or as in this case, without an undercarriage.

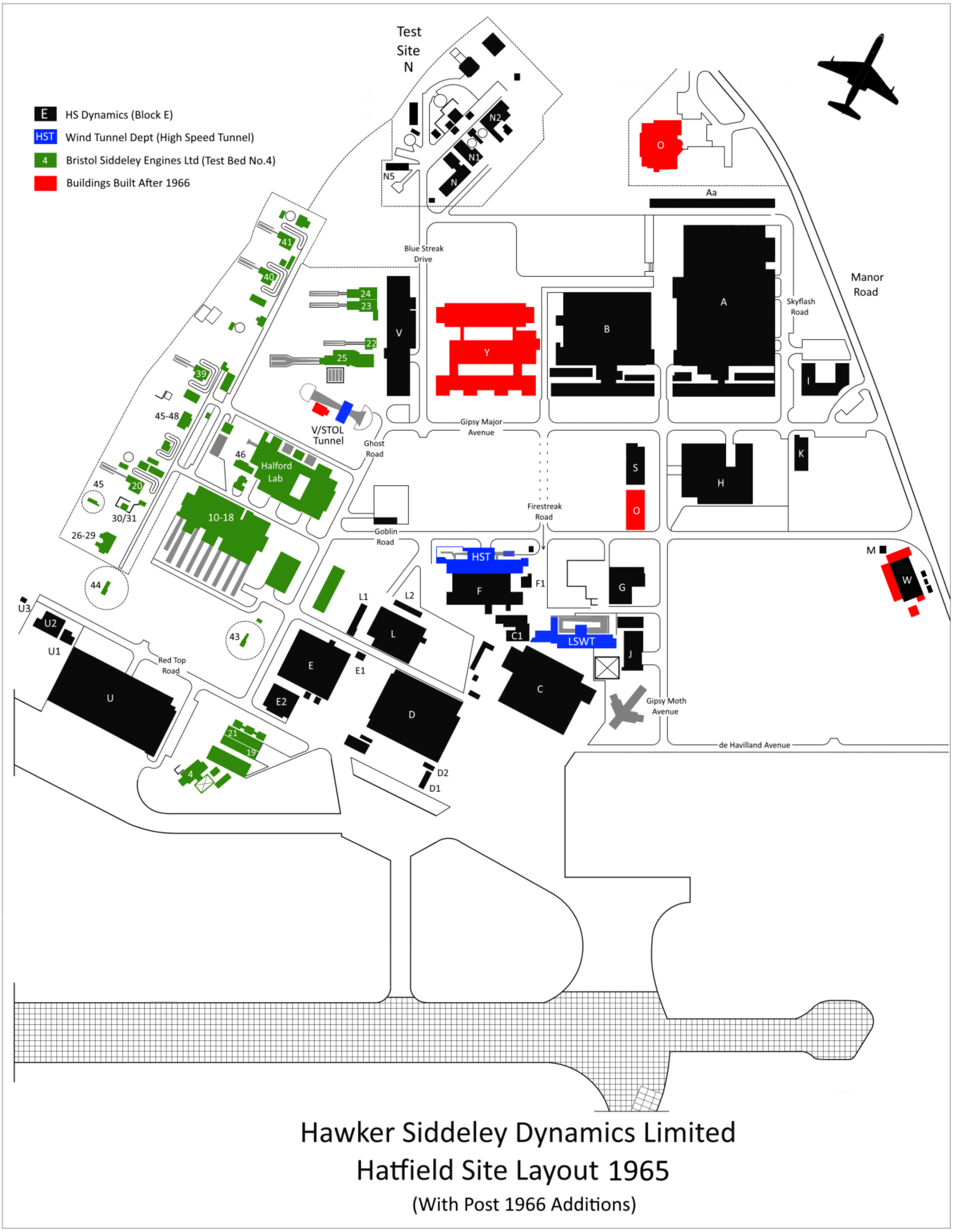

Fig.1: Site plan showing the position of the three wind tunnels within the HS Dynamics Site in 1965. Note that the chequered effect of the runway as drawn is because it was built with 15ft square, 10in thick slabs (outer slabs were 14in) to reduce temperature stresses – a rather novel, if not unique post-war form of runway construction. Part of the original wartime Merlin test bed colony is located between blocks 'U' and E2, while the remaining green coloured buildings became a development site for Bristol Siddeley Engines in 1960. The fatigue test tank (to the east of block 'C') was part of the aeroplane company.

Background

I briefly worked as a technician in the BAE Hatfield Wind Tunnel Department which was located on the BAE Dynamics site, Manor Road, Hatfield. It was situated adjacent to the Rolls Royce (RR) Halford Laboratory and engine development test facility, where I had worked previously. All of these sites were once part of the de Havilland Enterprise of companies based at Hatfield aerodrome, the original firms were, de Havilland Propellers Ltd, de Havilland Engines Ltd and de Havilland Aircraft Co. Ltd. The wind tunnels as well as the fatigue test tank originally came under De Havilland Aircraft Co Ltd.

A wind tunnel is a means of providing a steady wind of uniform and constant velocity in which a model of an aircraft can be held while the aerodynamic forces on it are measured. The air loads on the stationary body in a stream of air are the same as on the same body moving through still air at the same relative speed. Aeronautical wind tunnel testing generally falls into two categories, high speed and low speed. I was assigned to the 9ft by 7ft low speed wind tunnel (LSWT) from 1988 to 1992. The work in the LSWT varied from testing of the following types of models:

- Complete models manufactured for specific projects, this form of testing accounted for a high proportion of tunnel time.
- Half-models where higher Reynolds Numbers (RN)[1] were required for high-lift device development. This type of model was mounted on a false wall rigged on the starboard side of the working section whereas complete models were fitted to three struts in the centre of the working section
- 2D 'plank' like models of constant section from root to tip. The primary purpose of these was for the development of high lift devices (slat and flap). They had the benefit of a useful increase in Reynolds Number compared to a 3D half or complete model, as well as ease of manufacture. Their relatively large scale also enabled the representation of detail features in the slat gap and flap shroud areas.

Historically, the department had two other wind tunnels, the high-speed tunnel (HST) and the V/STOL tunnel (later known as the 15ft tunnel) although the HST had been removed before I worked there. The original tunnels therefore, were the HST and the LSWT which were built at the same time. The tunnels were supported by their own design staff, draughtsman and computer programmers who designed the models, rigs and equipment used in the tunnels. The testing and report writing was carried out by a test engineer assisted by a technician.

The bulk of the models were manufactured by the department's own model shop which was built as part of the 9ft by 7ft complex and which was doubled in size in 1961 to cope with an increase in volume of work. Models were manufactured to a high degree of accuracy using metal templates (from 1974 numerically-controlled machining), and using a wide-range of materials, such as mahogany, marine plywood, epoxy resins, aluminium alloy and high tensile steel etc. An instrument section looked after all aspects of tunnel and model instrumentation, including data acquisition, video and sound recording as well as all electronic equipment associated with the testing of powered models. The end product of the department was the technical data normally supplied as a 'Wind Tunnel Note' which gave a considerable amount of detail of the effect of airflow under a wide range of conditions on the item of interest to the customer department. These departments were 'Aerodynamics' or 'Research and Future Projects'.

Hatfield Wind Tunnel Department closed on 28 August 1992 although I stayed for a further year on a vibration and noise research project formerly part of the department, but funded by the Department of Trade and Industry. Just prior to closure, the bulk of the department's archives ended up in a 7-yard skip although I managed to save a number of photographs and some wind tunnel notes. All this material has now been catalogued and stored in the ARG archive at Alconbury (see the ARG Archive list, beginning on page 34).

I started to write up the history of the Hatfield wind tunnels in 1989 and completed the task on the closure of the Hatfield site. Since then I had miss-laid it but while cataloguing material at the Airfield Research Group's (ARG) archive at Alconbury I rediscovered a hard copy which I scanned for presentation here.

<u>National Grid References</u>

HST: TL 2099 0961. LSWT: TL 2109 0962. 15ft Tunnel: TL 2082 0963

[1] A model 1/10 full-scale would have to be tested at 10 times full scale speed, which is impossible; so the results of model testing have to be corrected to give full-scale results. This discrepancy between model and full-scale is called 'scale effect'. The Reynolds Number is a scale effect parameter dependent on both model size and airflow speed and pressure. The nearer the test RN is to the full-scale flight RN, the better.

Part One: High Speed Tunnel (No.52 Test Bed)

Three years after de Havilland began production of controllable-pitch propellers, a propeller test bed (affectionally called the 'Cathedral) had been constructed at Hatfield in 1938, During the Second World War, it became apparent that a test bed was required in which the engine and propeller were under test as a combination as the capacity to just rotate the propeller in the Cathedral was not sufficient. In 1943 the planning for the construction of a pair of test tunnels began.

In November 1947, a pair of test tunnels were completed for de Havilland Propellers Ltd, which was designed to test propellers up to 6,000 horse power (hp) and a diameter up to 20ft, but provision in the design to handle propeller turbines up 10,000 hp was included but this figure was seen as the eventual limit. The original idea was to have one tunnel testing in-line engines and the other testing radial engines of both liquid and water-cooled engines.

The architectural design work was carried out by James M Monro & Son, and the structure was constructed by Holland, Hannen & Cubitts Ltd. They were of 14-inch thick reinforced concrete in hexagonal form – a shape adopted to simplify construction. The facility consisted of a central rectangular block, housing twin control rooms, arranged back-to-back, flanked by two tunnels 215ft in length and 29ft across the flats of the hexagon, with a venturi-like working section 72.5ft long and a diameter of 22ft. This was constructed by the sub-contractor, Light Alloy Structures Ltd and at the time, was the largest aluminium structure in the country.

They were both equipped with Heenan and Froude test-wings to mount the engines on, and equipment was provided for measuring torque and thrust. Noise and vibration was kept to a minimum as the complete building was sectioned into ten parts, variously isolated between adjacent sections by compressed cork, felt or an air gap.

Plate 3: One of the test tunnels, the image shows the nearly completed test bed, June 1947. The venturi can clearly be seen and in the foreground, is a compressed air operated lift and platform used for the installation of engines and propellers. The Heenan and Froude test wing can clearly be seen along with the engine bulkhead for a radial engine.

Plate 4: View looking NW: the much-modified Nos. 51 and 52 test beds as seen in 1993 – the HST was located inside the right-hand test tunnel

Plate 5: No. 52 test bed side view, 1993

High Speed Wind Tunnel

Design of the high-speed tunnel (HST) started in 1952 and at an early stage it was decided that it was to be a turbo-jet powered, injection type tunnel incorporating three de Havilland Ghost Mk.50 engines. An early proposal was to build the LSWT in reinforced concrete and brick with a steel working section and the HST built above it. The ground floor of the building housed the LSWT working section with an under-floor balance at basement level, while the HST working section would have been at first floor level directly above it. The air intake for the three Ghost engines would have been a two-storey structure, and their exhaust was simply to have been expelled to atmosphere through a chimney stack. This idea was eventually scrapped and a new design was drawn up instead based around the northern half of the existing concrete propeller tunnel No.52 Test Bed. Only the test tunnel was required for the HST superstructure (not the shared control room although part of it became an engine workshop), a new control room housing the working section, tunnel contraction and part of the first diffuser was built on the northern side of the test tunnel.

Plate 6: Working on the conversion of the north propeller tunnel, August 1953 – view shows the framework that would support the tunnel superstructure immediately downstream of the engines. The splitter panels have yet to be removed to be replaced by the three engines and a new set of air-intake silencing splitters

Testing of models of the injector section and final diffuser took place using compressed air from the Combustion Research Department (later called the Halford Laboratory) of the DH Engine Company. This was passed through a Ghost engine combustion chamber to simulate engine exhaust at the required temperature and pressure. Tests were carried out at various mass flows and pressure ratios, and on the results the final design of the tunnel was established.

The contract for the construction of the HST tunnel circuit was awarded to GA Harvey & Co. of Greenwich, while the working section was manufactured by Foster, Yates and Thom Ltd of Blackburn, the firm of General Constructional & Engineering Co Ltd were sub-contractors. An application for the necessary steelwork licenses for both the LSWT and HST were made on the 8 September 1952 at the same time to the Ministry of Supply, with 320 tons of structural and sheet steelwork required for the HST and 250 tons for the LSWT.

The HST was completed by 23 December 1953, just 20 months from the design work being started and eight months after construction commenced. The original engines came from the prototype Comet airliner G-ALVG, and were first run in situ on 1 March 1954 with the working section by-passed. The whole tunnel was first run on 26 March 1954 and the first working model in the tunnel was a DH 117 intake model which began its test on 9 December 1955. This model is now in the de Havilland Museum.

Two of the four 5,000-gallon underground bulk storage tanks and pump house from the former test bed were utilised for the Ghost engines, fuel being fed to a 600-gallon header tank equipped with Comet booster pumps. The starting and control system reflected ordinary Comet practice, but with only three engines.

The induced airstream entering from atmosphere was taken through acoustic splitters in the intake silencing building. On leaving the silencing chamber, the air entered a honeycomb section where it mixed with recirculated hot gases from the engine exhausts. The air stream then passed through a 15ft long settling chamber containing two stainless steel screens before entering the contraction cone. The first screen acted as a filter to trap foreign objects and the other reduced any turbulence. On leaving the fixed contraction, the flow passed through the working section which comprised three areas. The first was the model position; the second the sting support strut and incidence rig for the model; and the last formed the transition into the first diffuser. After leaving the first diffuser, the airstream took a right-angled bend through turning vanes and then was swept upwards towards the injector section. Here it was mixed with the exhaust from the engines in a constant area duct that provided efficient mixing. The hot mixture then entered the main diffuser before the final exit duct. A proportion of the hot gases were collected by a large open-fronted aerofoil, turned through ninety degrees by means of cascades, and ducted into the intake honeycomb, where it was mixed with incoming cold air and the cycle continued (the return of hot gases to the tunnel intake prevented condensation in the working section). The remainder of the hot gases were simply exhausted to atmosphere through acoustic splitter panels.

The working section was originally 2ft square but was built in such a way that the width could be increased to 2ft 6ins at a later date. However, it was not until December 1964 that this modification was carried out, as it restricted the tunnel to subsonic operation.

The working section had removable side walls for access to the model. The top and bottom were formed by liners which were flush with the fixed contraction at their upstream ends. Originally three pairs of 8ft long liners were provided, one for the transonic Mach number range M = 0.5-1.2, one profiled for M = 1.4 and the third for M = 1.6. The transonic liners were slotted to minimise shock wave reflection, but the supersonic pairs were solid. The liners were mounted on screw jacks so that their angle of divergence could be varied. This enabled testing over a range of Mach number either side of the nominal value for the liner, and allowed precise calculations of boundary layer thickening to be made.

The doors giving access to the working section had inflatable seals which had to be pumped up with a bicycle pump. If these leaked while the tunnel was running a whistling noise would be heard which a few more pumps would cure.

The side walls had optical glass windows 20ins diameter through which the formation and position of shock waves at high Mach numbers could be seen and photographed using Schlieren apparatus. Full span models were attached to a rear sting supported by a vertical strut passing through the working section. Inside this strut were two lead-screws, geared together so that the combination of the vertical motion of the strut and angular motion of the sting allowed the model to rotate in incidence whilst remaining on the centre line of the working section. At a later date a roll mechanism was fitted enabling rotation of the sting about its axis. Thus, if 90-degree roll was applied to the model, operation of the incidence system now applied a sideslip relative to the airstream. Any combination of incidence and sideslip was also possible with intermediate roll angles.

Aerodynamic loads on the model were sensed by strain gauge balances measuring up to 6-components. These were of the Baldwin type and were fitted inside the model, whilst the data was collected by Elliott recorders, together with Pegasus Coded Digitiser Discs. These produced a printed output of raw data together with a punched 5-hole paper tape. By 1970 this system had long been obsolete and very difficult to obtain accurate results; it was therefore replaced with a new Data Logger system.

The testing of half-models (such as the Hawker P1154) employed the false wall technique, the model being connected to a 4-component balance cage outside the working section. All the balance equipment was designed by the instrument laboratory attached to the wind tunnel department.

The three engines were run from the engineer's desk in the control room. The operator was provided with three sets of throttles, engine rpm, oil pressure and jet pipe temperature gauges, low and high pressure fuel cocks and a very

sensitive micro manometer Mach number gauge. The max continuous rating was 9,750 rpm, although engine rpm would vary depending on what Mach number was required. A typical test on a model configuration at several angles of incidence and Mach numbers took about 3 hours, the engines consuming around 2,400 gallons of kerosene costing l/4d per gallon at 1970s prices.

An observation cubicle (the 'goon box') was located below the engines where an observer (usually an apprentice) sat while the engines were running, watching for any signs of trouble such as fuel or oil leaks. He was in direct communication with the operator in the control room, and in the event of a fire he would close an LP fuel cock and pull a lever to discharge a bank of Co2 fire extinguisher bottles. This, in fact, happened on only one occasion when an apprentice accidentally pulled the operating cable.

When the engines were running at high rpm the tailpipes became so hot that it was possible to see the exhaust cone through the semi-transparent tailpipe wall.

As a way of conserving engine life, a guillotine door was installed later between working section and injector, so that the engines could continue running instead of being shut down each time it was necessary to carry out an adjustment to the model.

Between 1962 and 1968 Ghost 48s were purchased and replaced the Ghost 50s as these became unserviceable. New glass fibre air intake ducts had to be made to suit the bifurcated air intake of these ex-DH Venom engines. The first pair of these from the contractors was made with polyester resin, and when the engine was run the radiated heat caused the bell mouth to collapse, fortunately after the engine had been shut down. New intakes were manufactured in epoxy resin and no further problems were encountered. Around 1970 it became necessary to recondition the HST due to deterioration of the tunnel structure and shortage of engines and spares, particularly the flame tubes. A number of schemes were therefore proposed:

- installing the Rolls Royce Nene engines from the redundant Handley Page HST,
- replacing the current Ghost engines with two Rolls Royce Avon engines. In fact, four Avons were bought and design work was carried out, but despite an estimated 20% saving in fuel, the idea was shelved. Or alternatively:
- build a new tunnel of the intermittent blow-down type, based on the existing tunnel at Brough.

In the event, parts of the badly corroded tunnel structure were either replaced or renovated, and Ghost 50 engines and spares were purchased after a world-wide search.

As an adjunct to the HST an engine intake test rig was erected within a compound at the western end of the HST, this was built in 1955 to aid the development of the de Havilland H4 (Gyron) gas turbine engine. The flow induced through the intake rig by-passed the tunnel working section by means of a large door closing off the normal circuit. Mass flows of 320 Ib/sec were possible and the rig was used to test full size engine intakes, such as Comet, Trident and Nimrod as well as aircraft de-icing systems. In the 1960s an observation room with banks of manometers was built, positioned at one corner of the now extended compound.

The last run in the tunnel was on 10 July 1980 on a 1/7 scale 125-33 rear end model, and the tunnel was finally dismantled in May 1983. The working section is now preserved at the Science Museum, Wroughton, Wiltshire.

High speed work was then transferred to the 9ft by 8ft tunnel at the Aerospace Research Association site at Bedford or the 8ft by 8ft tunnel at the NAE Bedford.

Typical models tested in the HST included the following:

- 1/75 scale DH Comet half-model: the effects of Whitcombe bodies, dive brakes and fuel tanks
- 1/53 scale and 1/82 HSA Trident half-models: wing development, longitudinal stability, fillet development and wing fences
- 1/46 scale HS Trident rear-end model: pressure plotting and various oil cooler, Auxiliary power unit and engine additions
- Hawker P1150/54 intake models: pressure plotting around intake lip for different lip shapes
- Hawker P1154 half-model: longitudinal stability, tail power and wing pressure distribution
- 1/35 scale DH 125 complete model: effect of tailplane December 1961
- 1/80 and 1/79 scale HSA / Airbus half-models: wing development, pylon development and flap track fairings.

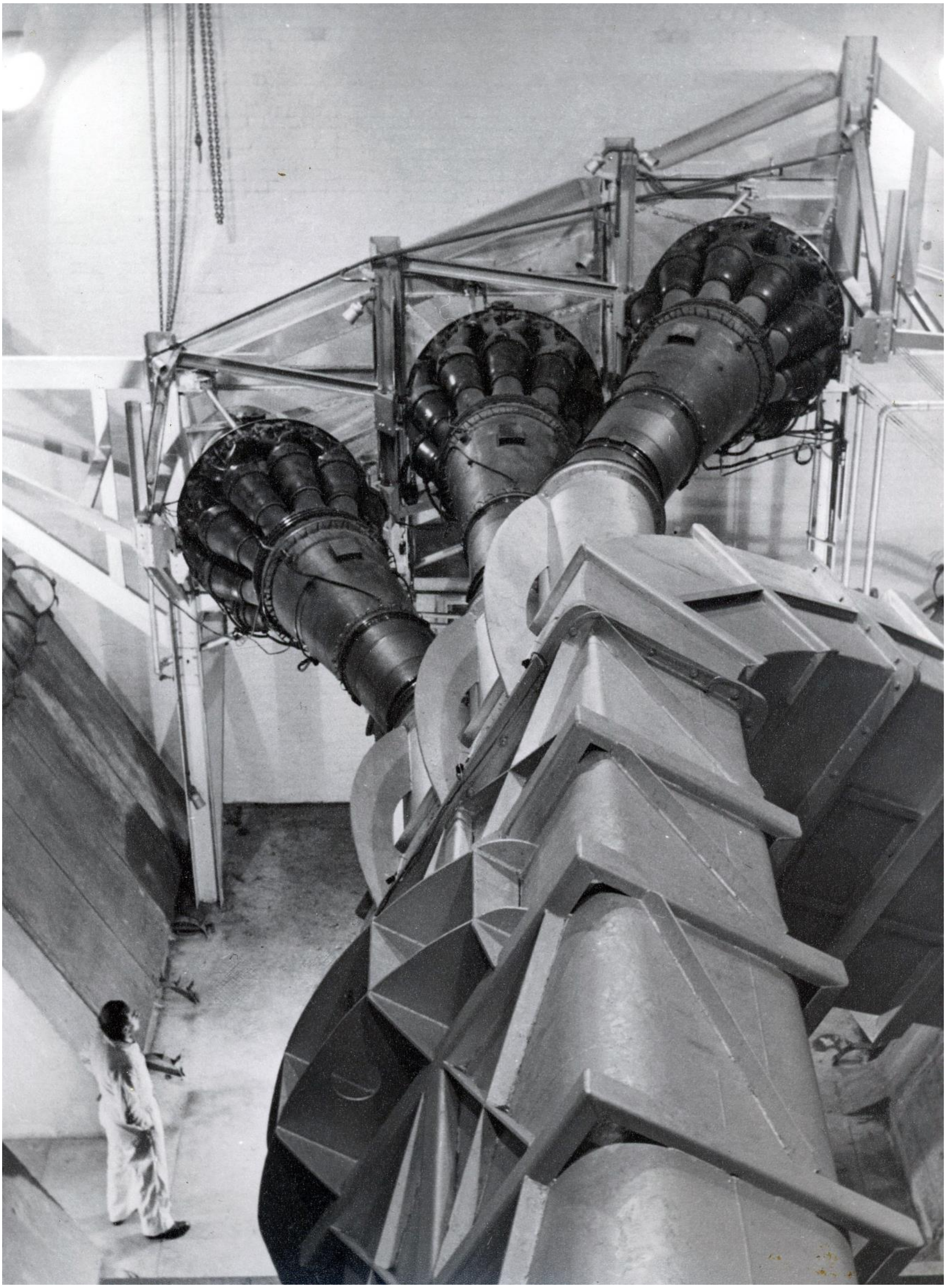

Plate 7: The injector nozzle area of the newly completed HST as seen in 1954. The three Ghost 50 engines being removed from the prototype Comet aircraft

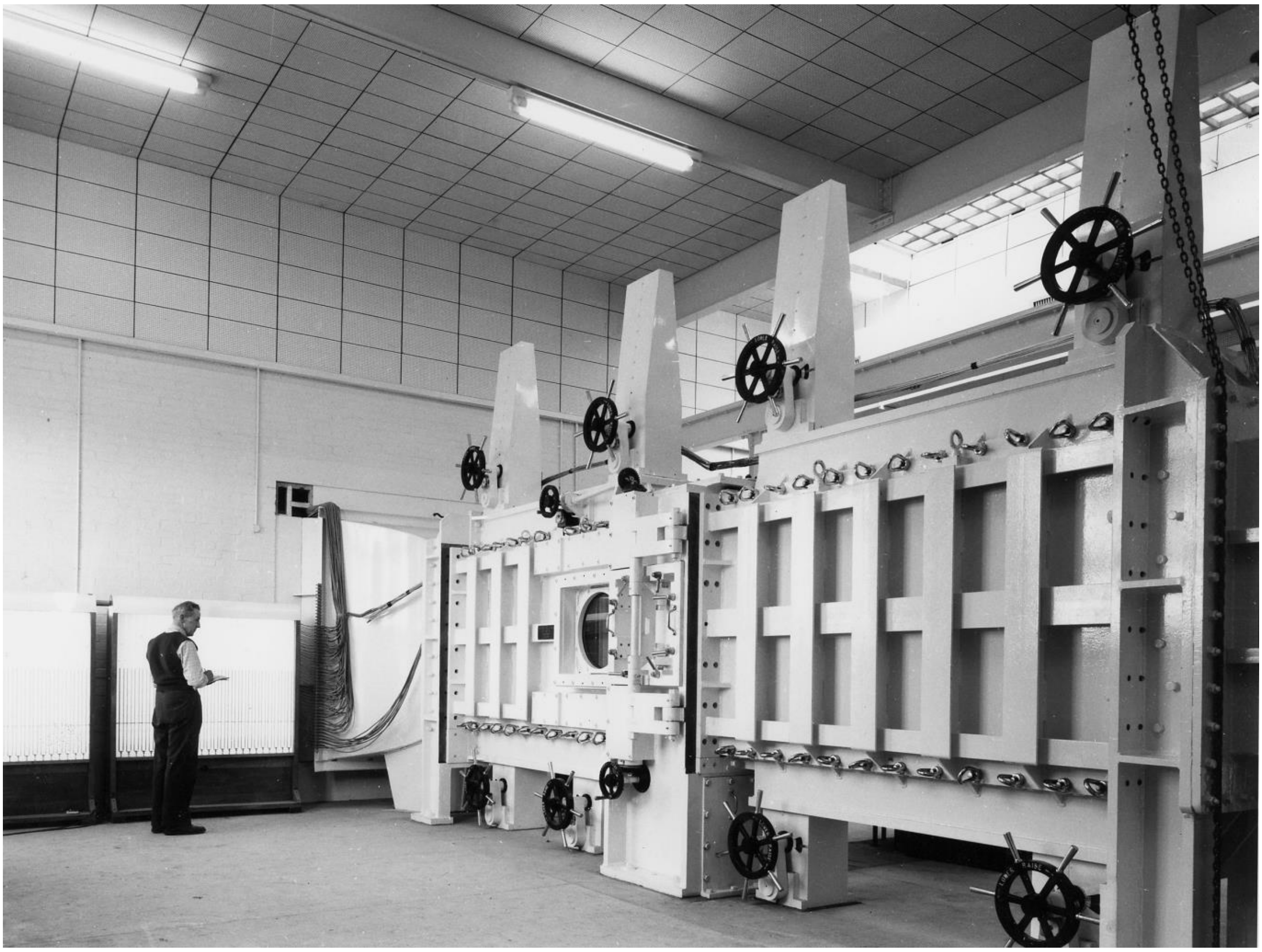

Plate 8: The HST working section and control room 1955

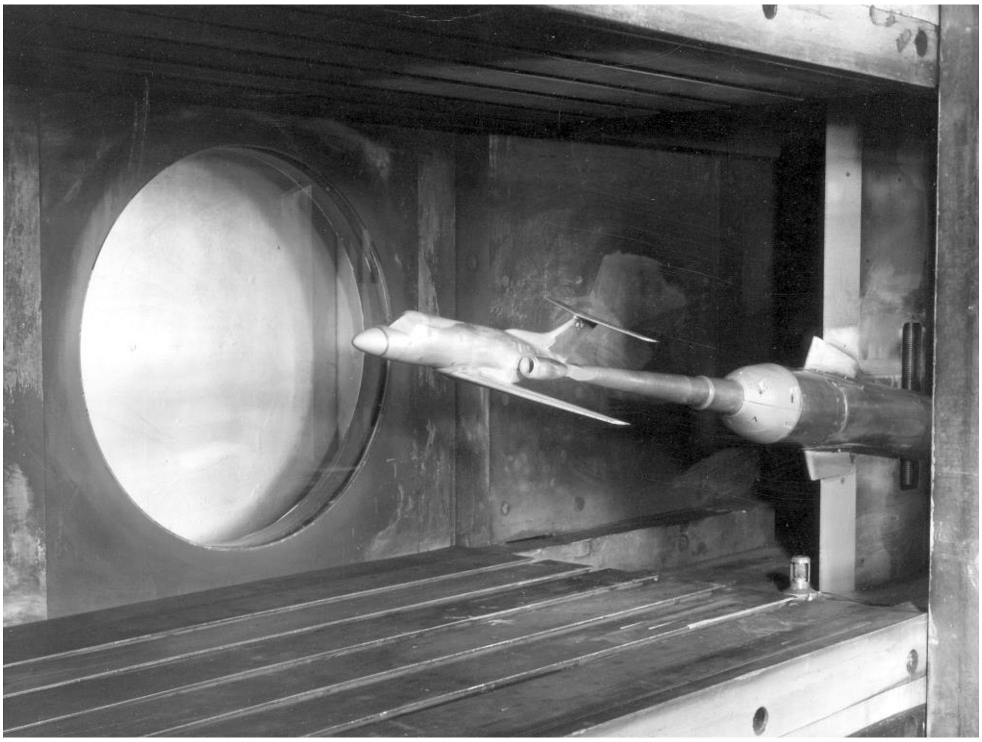

Plate 9: Sting mounted DH 125 1/35 scale complete model inside the HST working section 1965

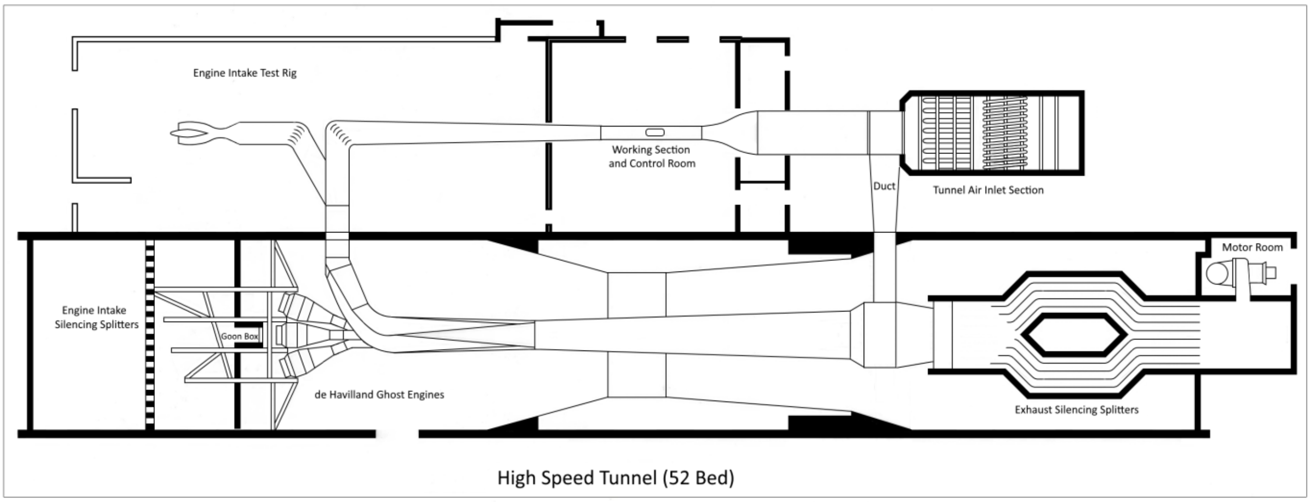

Fig 2: Plan of high speed tunnel with engine test rig in its original form (before extension)

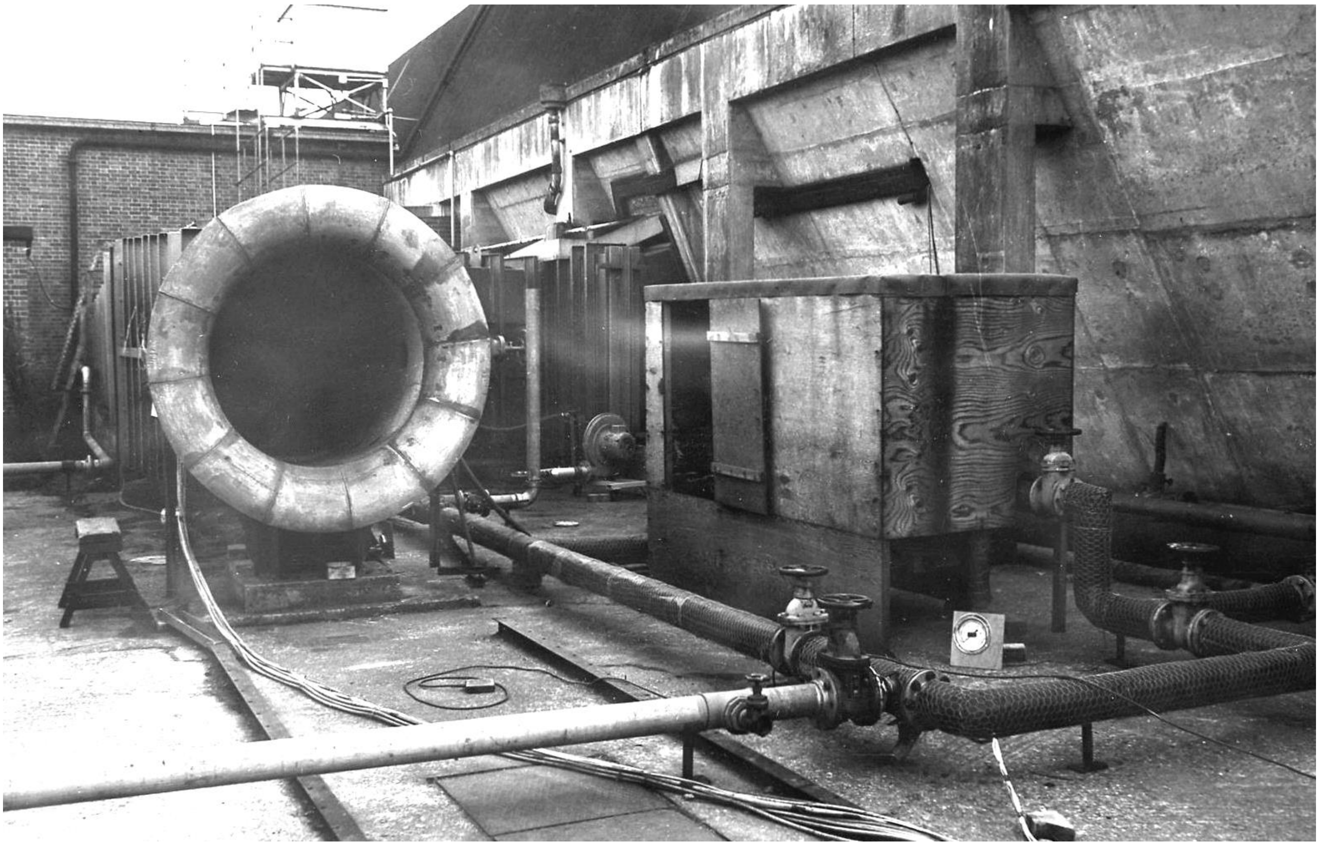

Plate 10: The intake test rig adjacent to the HST (52 test bed)

Part Two: Low Speed Wind Tunnel

In conjunction with the de Havilland Aerodynamics Department under the direction of GW Trevelyan and JA Kirk, the architects of both the LSWT and the HST were James M Monro & Son, of Watford[2] who were responsible for virtually all buildings located on the Hatfield aerodrome.

The design of the LSWT was based on the 1948 SBAC Committee recommendations for a typical industrial tunnel. After consideration of the range of Reynolds Numbers required and the economics of the system, it was decided to erect a 9ft by 7ft return circuit tunnel driven by a 500hp motor capable of speeds up to 250ft/sec for the testing of models up to 75ins wing span.

The contract for the main structure was given to GA Harvey & Co on 24 November 1952 at the same time as the high-speed tunnel and the first frames were delivered on 20 October 1953. The shell and frames were pre-fabricated and welded together on site and construction was completed in May 1954. In fact, it took just seven months from the delivery of the first frames to completing the main build, with screen, cascades and fan, etc. The tunnel first ran on 31 March 1954 (before it was finally completed). The first model, a 1/7 scale DH 110 began its test on 5 August 1955.

From the working section the airstream passed into the first diffuser and then to the first corner cascade where it took a 90 degree turn into a short cross leg, followed by a second comer cascade. After this second set of vanes, came the drive shaft and fan, followed by the main diffuser, some 87ft long, leading to the third and fourth comer cascades. Downstream of the fourth comer was a 17ft high and 22ft wide stainless steel woven gauze screen in a settling chamber. Finally, the air entered a 5:1 contraction cone to speed up the flow before it reached the working section. At the downstream end of the working section was a series of atmospheric breather slots, these prevented excessive build-up of air pressure due to dynamic braking of the fan during an emergency shut-down.

The four-bladed fan was 12ft in diameter and made by Airscrew Company and Jicwood Ltd. of Weybridge. The 500hp DC motor used a Ward Leonard system consisting of an AC motor driving a DC generator set, built by British Thomson Houston Co. Ltd. To save the fan blades from any serious damage a peripheral ring of balsa wood within which the fan rotated absorbed any foreign bodies, thus preventing jamming between blade tip and tunnel shell.

Tunnel speed was measured on a Betz manometer, from the static pressure difference between settling chamber and working section entry.

The working section measured 18.5ft long, 8.7ft wide and 6.7ft high with comer fillets. It was made of one-inch thick plywood supported in a steel frame, and built by Flexo Plywood Industries Ltd. Full view from the control room was given by a large window. On the opposite side of the working section was a small workshop, from which a large door in the tunnel side gave access to the working section for model installation.

When first built, there was installed above the working section a 6-component virtual centre balance designed and manufactured by Test Equipment Ltd. of Crawley. This balance was developed from the National Physical Laboratory (NPL) Warden balance. The forces acting on the model were transmitted to the balance by wing struts and a wire attached to the rear fuselage. The model was suspended at the virtual centre, and was mounted upside down in the tunnel. Model incidence was controlled by an electric winch which wound the tail cable. To maintain tension another cable from the rear fuselage passed through the tunnel floor, and carried a heavy weight suspended in a container of oil to damp out vibration.

The balance could read all 6-components simultaneously and independently by means of motorised steelyards operated from the control desk. The readings were transmitted through selsyns, the load values being read directly from the control desk. Model incidence and yaw were also adjusted from the control desk.

This balance had problems with interferences between the components; interactions were supposed to be eliminated by 'take-out' mechanisms which were never made to work correctly. In addition to this a number of different metals were used in the construction and, as a result, the measured values drifted with temperature. The performance was far from satisfactory, and it was therefore decided to replace the Test Equipment balance with an under-floor Grubb Parsons (GP) 6-component balance, which had become redundant in 1953 from the 10ft x 7ft high speed tunnel at RAE Farnborough. The GP balance was purchased in 1955, and was re-erected under the 9ft x 7ft tunnel; provided with modifications, new wiring and flexures, and was calibrated and ready for use in 1957.

A before, all six components were read simultaneously and automatically, with the measured values displayed on the control panel. Each force or moment was transmitted to a weighbeam which operated in the same way as an ordinary station weighing machine, where a jockey weight travels along the beam and weights (drop-weights) were added to the end of the beam. The measured load was expressed on the control panel in terms of the drop-weight value and rider position. The outputs from the balance, model incidence and sideslip as well as airspeed were digitised for direct input to computer programmes.

---

[2] The firm of James M Monro & Son had won a competition in 1932 for the design of the de Havilland factory and since then had designed most the buildings on the aerodrome at Hatfield as well as the Art Deco admin building at the Blackburn Aircraft factory, Brough and another Blackburn factory at Dumbarton. The son, (also a partner) was Geoffrey James Monro (b.1907 d.1985) who was almost certainly personally responsible for the de Havilland and Blackburn buildings.

The two main struts were mounted on slide boxes so that the strut spacing could be set to any desired value depending on the model type. The balance incorporated a turntable to yaw the model up to 30 degrees in either direction. Model incidence was altered by the movement of a tail strut connected between the balance pitch beam and the rear fuselage of the model. The balance configuration could also be changed for a half-model, in which set up, one main strut was attached to the wing and the other to the fuselage of the model. This strut was in fact, hidden inside a false wall which acted as a reflection plane and was near the cut face of the fuselage, but not actually touching it. Model incidence was adjusted as before by movement of the tail strut, now offset from the tunnel centreline on a cantilevered arm attached to the pitch beam.

Amongst many other types of aircraft models being tested under different configurations, various tests were carried out on Airbus, 125 and 146 models to determine the effects of jet efflux on the aerodynamic forces (interference effects) while using forward thrust or reverse thrust. The model was mounted on the balance (live) via three struts in the normal way, but in close proximity to a ground board for reverse thrust tests. The engine nacelles were independent of the model so that jet thrust was not applied to the balance and were attached to the compressed air feed system, the incidence angle of which was variable using a quadrant, motor and trolley assembly (earth). Any change in model incidence was followed by a similar change of engine nacelle angle. Both fan cold stream and gas generator hot stream thrust reverser systems were tested at representative thrust levels. Typical early test series in the LSWT included the following:

- Folland Gnat Underwing Fuel Tank Jettison Tests – September 1955
- 1/12 scale Spectre Nacelle from the Bristol Brigand jettison tests - April 1956
- 2/7 scale DH 112 Venom 1956
- 1/10 scale Vickers Vanguard to determine rudder hinge moment characteristics with various horn sizes
- 1/7.5 scale DH 117 mixed power-plant supersonic fighter 1957
- Full-scale Vickers Anti-Tank Missile – May 1957
- 1/14 scale Hunting H.107 aerodynamic characteristics – July 1958
- 1/4 scale HS 121 (K3) complete model 1960 and then converted to HS 132 (1965)
- 3/20 scale HS 135 (BH200) swept wing half-model 1969
- 1/18 scale C.10 suck-blow half-model (V/STOL civil airliner) research model with suction and blowing on 8 engines - 1970

The last test series was a Jetstream 41 aileron model, and the final run was on 3 August 1992. The tunnel was dismantled in December of that year and moved to Glasgow University where it was rebuilt in essentially in its original form, but with a new thyristor-controlled drive system. It was commissioned on 4 July 1997 and is now known as the 'de Havilland Wind Tunnel', it is still operational.

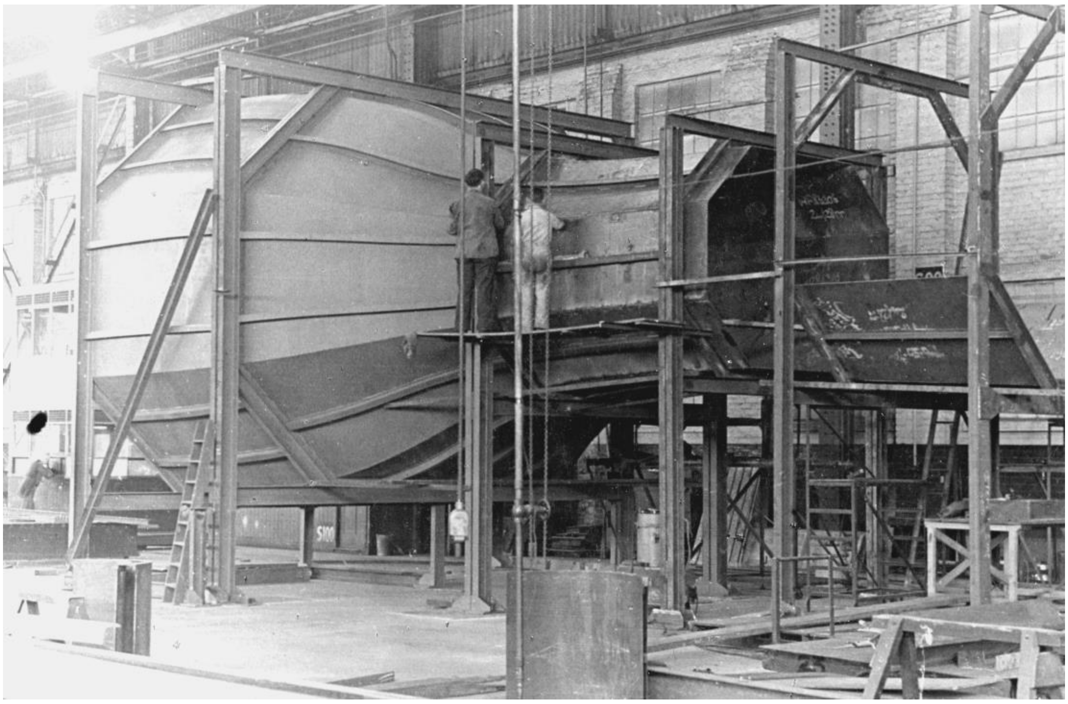

Plate 11: The tunnel contraction section being fabricated inside GA Harvey and Co's factory

Plate 12: The LSWT site under construction, September 1953

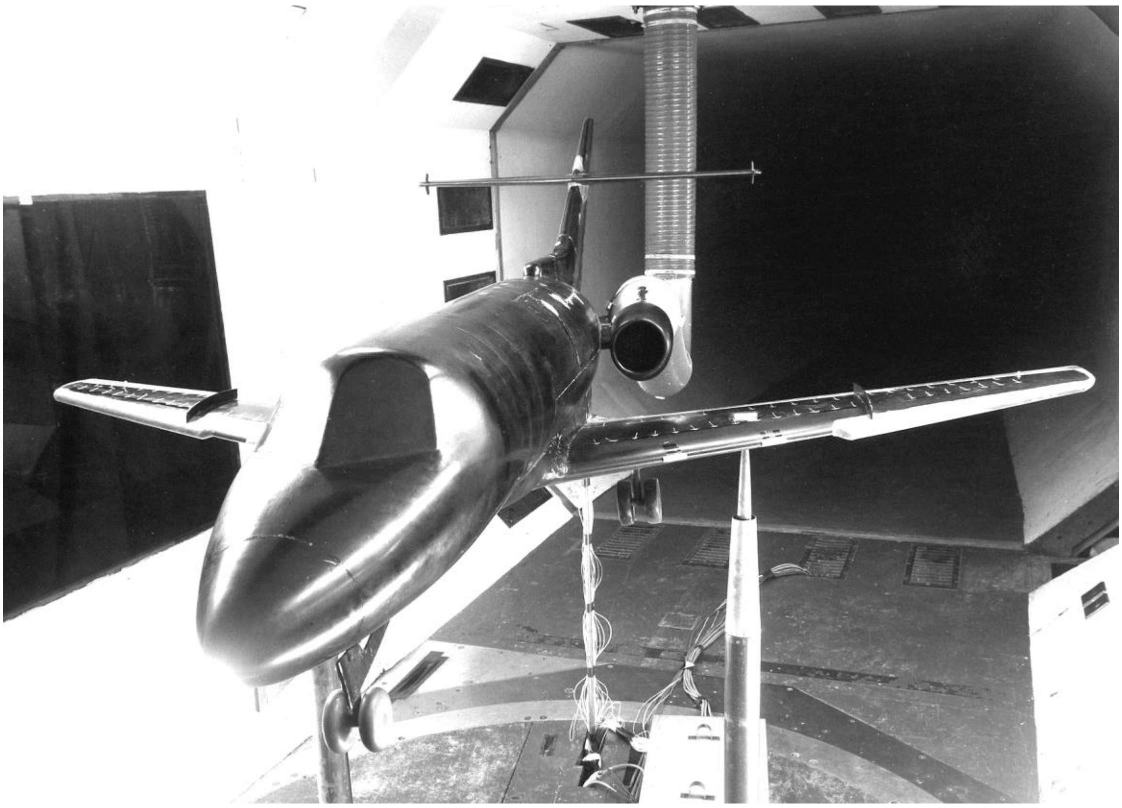

Plate 13: 1/7 scale HS 125-01 model with suction rig attached, 1975

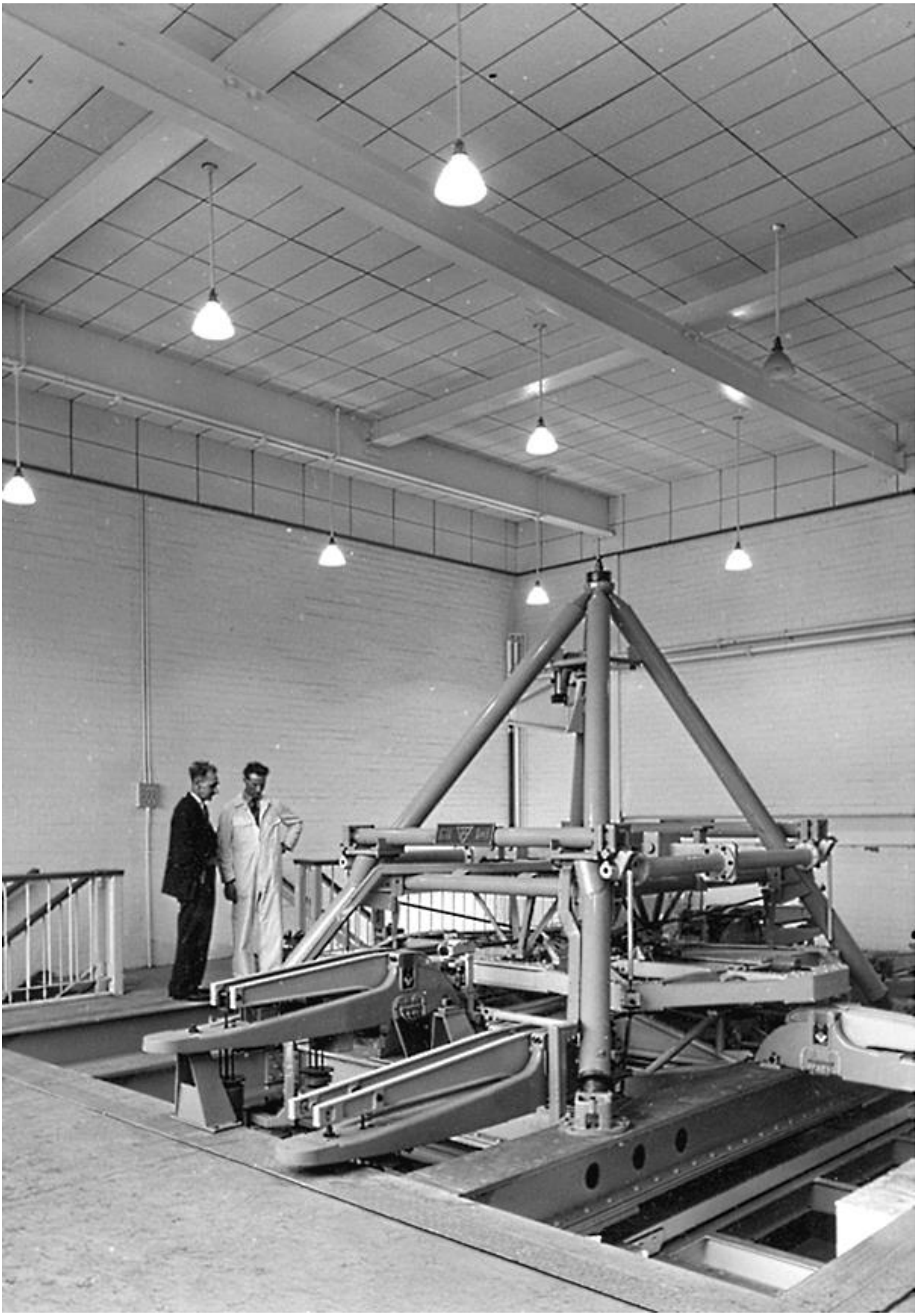

Plate 14: The original overhead Test Equipment balance above the working section, June 1954

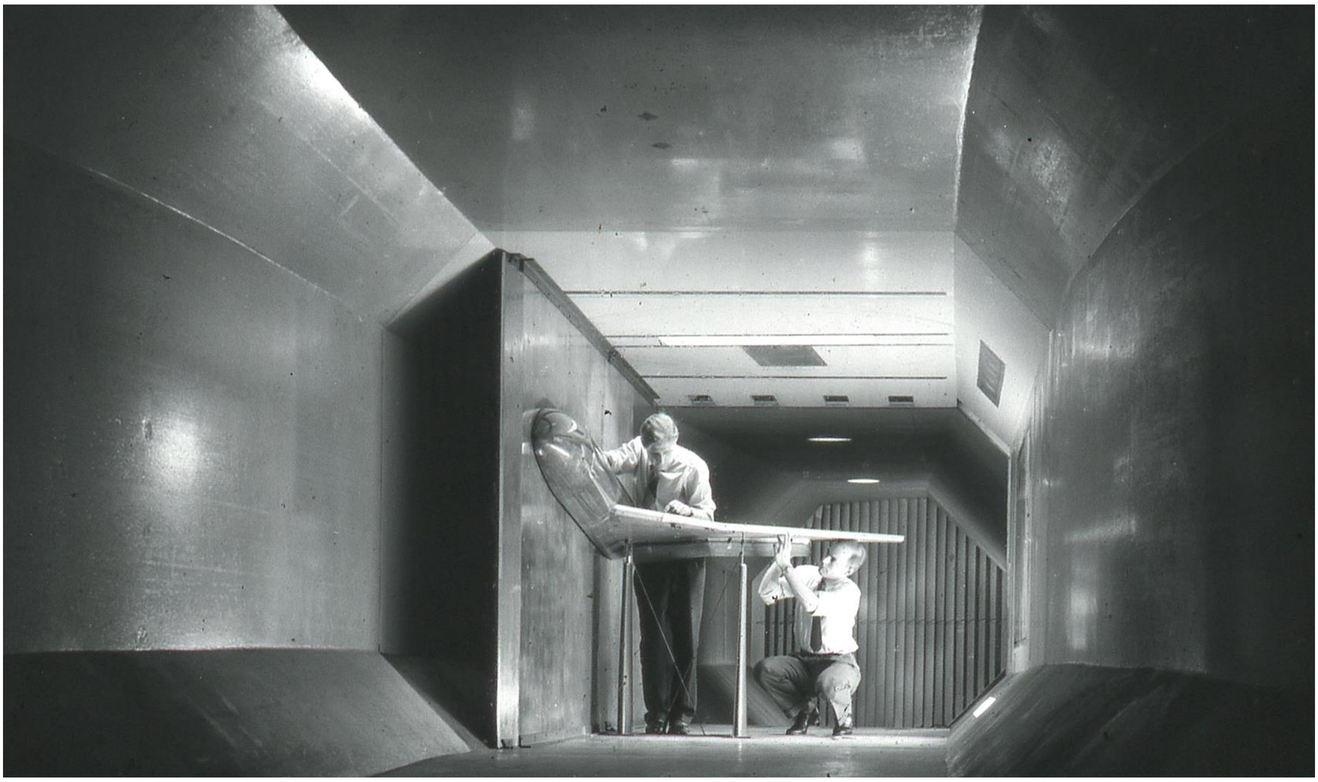

Plate 15: View looking towards the working section at a half-model being worked on. In the distance, can be seen the first corner turning vanes

Plate 16: The LSWT 3rd and 4th corners of the tunnel superstructure – view looking north-east. After the 4th corner can be seen two parallel girders denoting the position of the stainless-steel mesh screen. To the left of this is the contraction (shown by the reduced in size framework. The tunnel structure then enters the building and becomes the working section with control room adjacent to it. After the model shop was extended, this view would be of the extension which hid the tunnel from view.

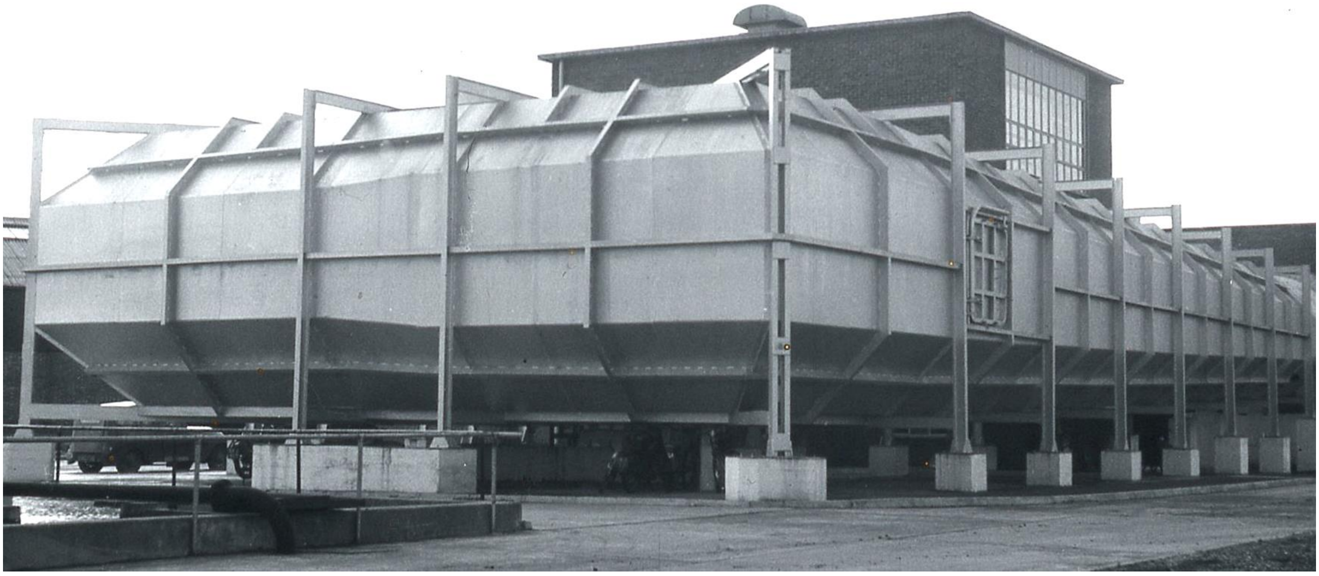

Plate 17: Third and fourth corners, view looking north-west with water tank in the foreground (left). The tall brick and glass structure is the first floor over the working section that housed the original overhead balance. The fan section is just out of view far right. The third diffuser seen in the foreground has an inspection door just before the third corner.

Plate 18: Interior of model shop in its original form, 1954

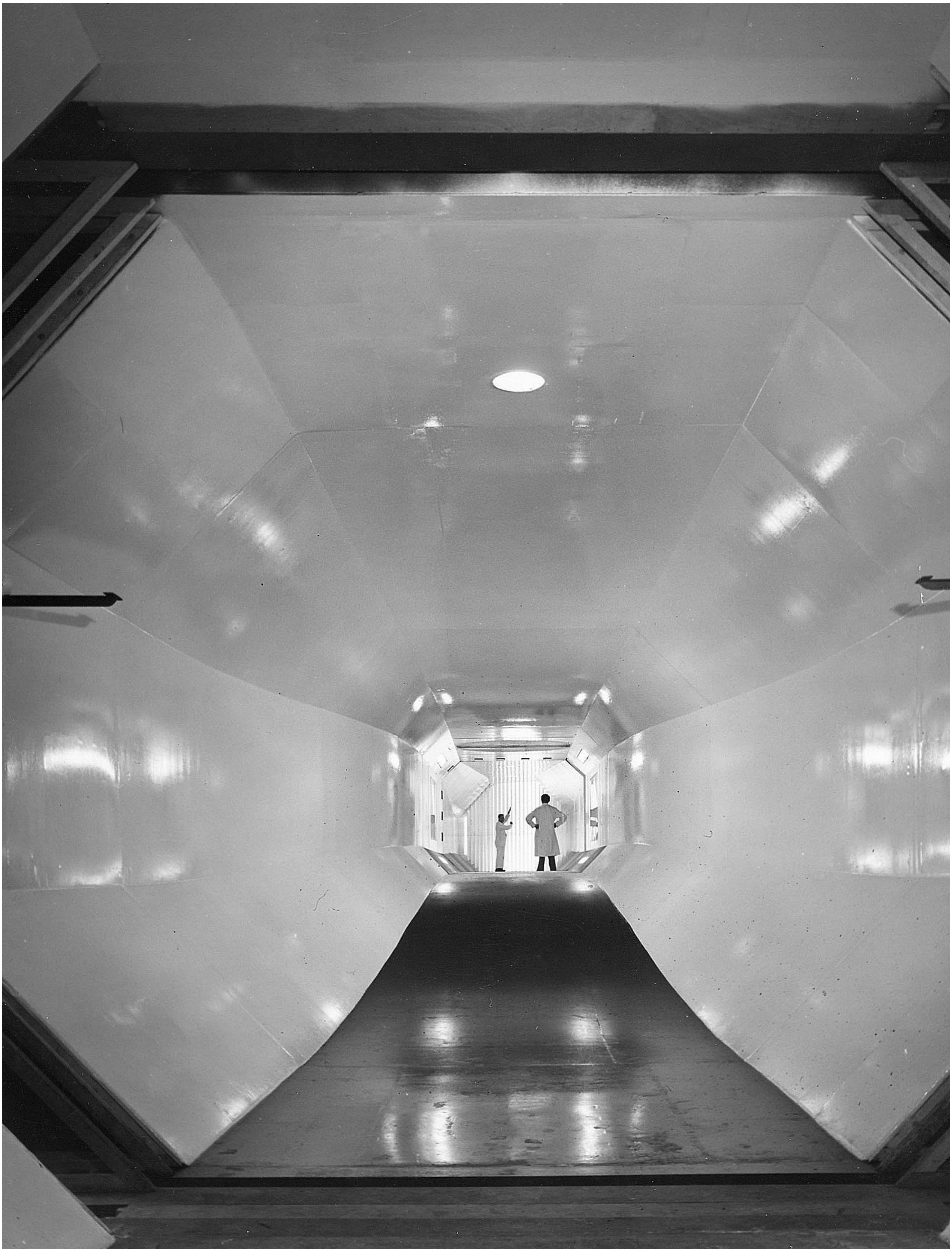

Plate 19: Tunnel 5:1 contraction looking towards the working section of the newly built wind tunnel 1954. The first corner vanes are just beyond the tunnel staff. Behind the photographer is the screen section.

Plate 20: HS 146 complete model, 1975

Plate 21: The same model with oil flow pattern after a run c.1990 – note the oil flow stain on the corner vanes

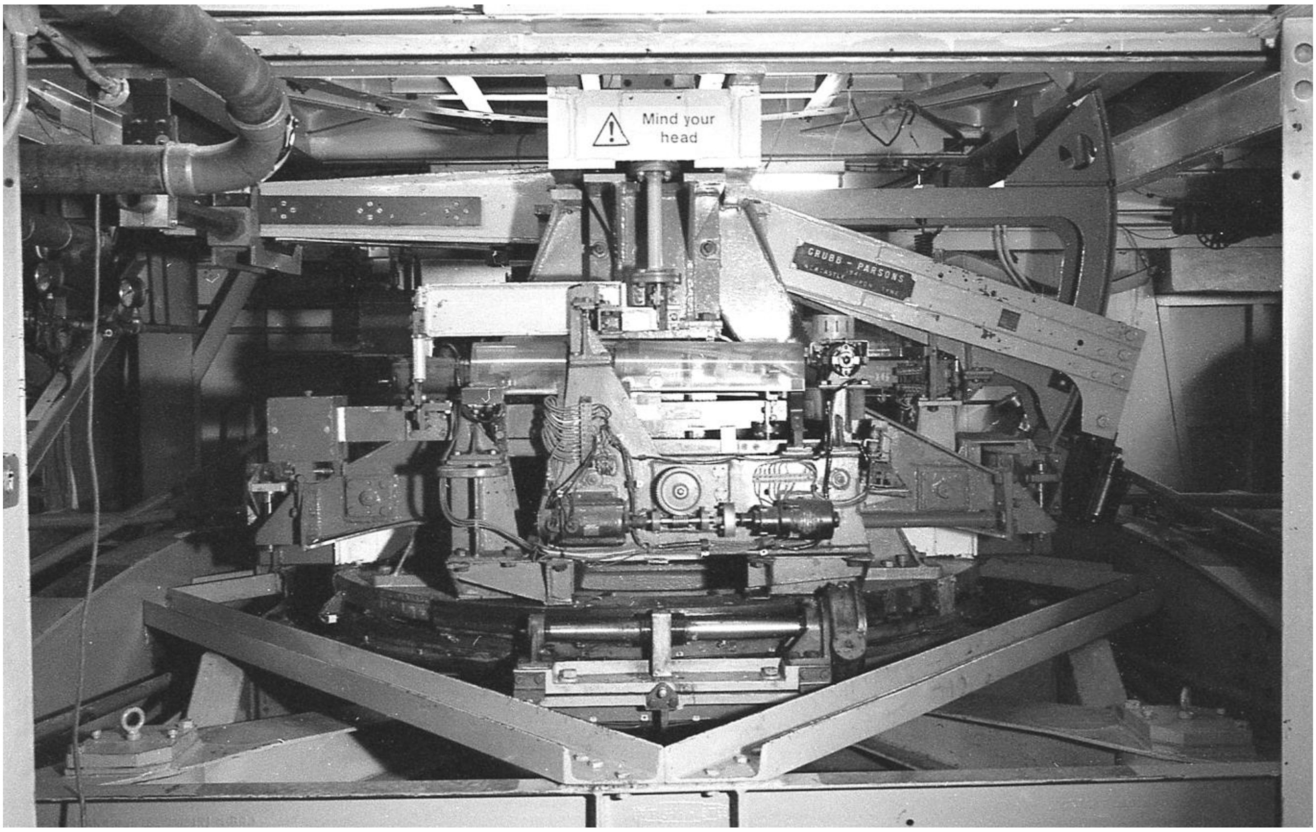

Plate 22: The underfloor Grubb Parsons balance, 1989

Plate 23: The LSWT building minus the 9ft by 7ft LSWT! 1993

Part 3: V/STOL (15ft) Tunnel

In 1960, member companies of the Hawker Siddeley Group (Avro, Armstrong Whitworth and de Havilland Aircraft) were in direct competition to submit an outline design for a vertical and or short take-off and landing (V/STOL) wind tunnel with a 15ft x 15ft working section. In March 1962, a detailed design study was authorized by the Hawker Siddeley Board of Directors for a V/STOL wind tunnel with an open return layout to be built at Hatfield. A major factor in the choice of the Hatfield site was the availability of large quantities of compressed air for powered models from the then Bristol Siddeley Engine Company (Rolls Royce from 1966).

Two schemes were originally considered, one for the conversion of an existing propeller test tunnel (No. 51 Test Bed, next to the HST) and the other for a completely new facility on a vacant site.

After much debate, the new site was considered superior to the proposed conversion as the tunnel design would not be restricted by an existing building. Furthermore, the Dynamics Division still had a requirement for the remaining propeller tunnel, which continued in use for several years.

The older style of open circuit design for the new tunnel was chosen on grounds of cost and of immunity from disturbances due to the recirculation of model wake, lift engine exhaust flows and boundary layer control air etc. A further advantage was the elimination of airflow contamination from smoke used in flow visualisation as well as from gases used in engine flow representation. It was argued that a single but long diffuser would be more efficient than a closed return circuit with comer vanes producing losses in the order of 40% of the total power input. A large intake area protected by screens would minimise the effect of external winds, which were the main problem in the use of an open circuit arrangement.

Initial model tests were carried out in 1962 in the settling chamber of the 9ft x 7ft tunnel to determine the effects of external winds on an intake with mesh screens. These were made on an Armstrong Whitworth 1/34 scale model tunnel having a working section of 5.25ins square. In March 1963, a new 1/24 scale tunnel with a representative working section, diffuser and fan section was also built and tested. The final aerodynamic design of all the component parts of the new tunnel was established from the results of tests carried out on these two models.

Plans, elevations and sections were drawn up by Monro and Partners (formally James M Monro & Son), Watford, and these were submitted on 22 February 1963 and in the following month construction commenced. The intake, contraction and diffuser was of welded steel construction with 3/16-inch plate welded to a steel framework while two transition sections were of 1/4-inch steel plate. The exit section contained the mounting framework for the fan motors. The main contractor was GA Harvey & Co. but the working section was constructed in-house by the Hatfield model makers, the inner skin being Warerite faced plywood.

The working section was 15ft square with comer fillets and had a length of 40ft. It also had a hydraulically raised ground board which spanned the tunnel and extended 10ft upstream and 10ft downstream of the centre of the working section. The ground board could be set at any height from the centre of the tunnel to fully retracted, flush into a well in the tunnel floor. Large doors upstream and downstream could be closed to isolate the working section, both for taking 'wind off' measurements and while rigging the models. One sidewall opened for model access from a workshop area. At 15ft square the working section could accommodate models of up to 135ins wingspan at speeds up to 140ft/sec achieving a Reynolds Number of up to 2 million, depending on the model. Where a higher RN was required, tests were generally done in the 5-metre tunnel at RAE Farnborough where an RN of up to 9 million was possible. Airflow was generated by a multiple fan arrangement consisting of seven 10ft diameter, two-bladed fans, each driven by a 100hp electric motor. Power was supplied by a mercury arc rectifier from the 3-phase AC supply.

The tunnel was primarily intended for the testing of models of V/STOL type aircraft, therefore a supply of high pressure air to the tunnel was a major facility. There was available up to 20lbs/sec of air up to 100lbs/sq in gauge pressure from the Halford Laboratory nearby. The very nature of V/STOL models involves high pressure air as:

- the primary lifting device, such as lift jets (Harrier), or
- as an assistance to high lift (boundary layer control), or
- to drive rotary lifting devices (fans, propellers), or
- thrust augmentation and/or intake flow induction.

V/STOL models (injector devices) were mounted upside down so that the strut mounting system would not interfere with the engine efflux. The 'bare bones' without airframe were tested first with tunnel wind off but with compressed air flowing through the engines, and the balance forces were recorded over a range of efflux angles. This was to establish the engine thrust in order to subtract these values from the total loads measured on the complete model. A major object of testing V/STOL models was to examine the transition from jet-borne to wing-borne flight. As an example, the Harrier GR3 model weighed some 300Ibs and could produce 400Ibs thrust (in theory more than enough to support itself).

The tunnel first ran on 2 March 1964 and during initial work to calibrate the tunnel the airstream showed that the design of the front screen was not satisfactory. Further tests were therefore carried out with the 1/24 scale model tunnel mounted on the ground board turntable in the working section. As a result of these tests it was decided to:

- fit a solid roof between the tunnel intake and the front screen,
- increase the radii of the side intake lips and
- fit a honeycomb flow straightener inside the contraction.

Because of these modifications the tunnel flow proved acceptable, although still not ideal.

The cheapest option for a balance was to make use of the redundant Test Equipment balance above the 9ft x 7ft tunnel. This would however have needed extensive modifications before being rebuilt above the V/STOL tunnel. It was quickly decided that this balance would not be suitable for use with powered V/STOL models, and eventually it was scrapped. The actual balance installed beneath the tunnel was a Grubb Parsons virtual centre balance with forces frame and moments table floating on air bearings, but with the lift system hung on flexures. The load capacity of the balance was about double that of the 9ft x 7ft tunnel balance on lift and side force, but of a similar magnitude for the other four components. Weighbeam balancing was automatic and simultaneous on all six components. Readings were originally recorded on 5-hole punched tape (like the other tunnels), but latterly were output direct to a PDP11 computer.

In order to save time and money it was decided to use the design of the balance in the No.2, 11.5ft x 8.5ft tunnel at RAE Farnborough. Several modifications were incorporated, namely an increased height of the virtual centre to suit the larger working section of the V/STOL tunnel; the addition of an air chamber to reduce wear when yawing the balance, and a reduction in the stiffness of some flexures to increase sensitivity. The balance was housed in a near air-tight room beneath the tunnel working section. The room was sealed to minimise the escape of air to the (low pressure) working section via the strut guard(s), thus preventing a possible cause of interference with the flow of the model. The compressed air for the balance air-bearings was provided by an on-site compressor. Complete models were normally mounted on three struts, or on a single centre strut or a gallows rig for blown models. Half-models were mounted wing vertically on a short single strut near the partially raised ground board, which functioned as a reflection plane. In this configuration model lift was recorded as side force and pitch became yaw.

Because V/STOL aircraft can hover and move in any direction, including vertically up or down, testing a model in a tunnel meant that the rig needs ranges of +/- 180 degrees of sideslip and +/- 90 degrees roll, in addition to passing several thousand cfm of compressed air. The gallows rig was the solution to this. The vertical strut was mounted offset from centre on the balance to position the model at the virtual centre. Rotation of the balance turntable gave sideslip and rotation of the sting about its axis gave roll. The supply of compressed air to models had to be carried out without compromising the freedom of the balance to sense the aerodynamic loads on the model. The pipework incorporated either an air-bearing connector to transfer air from 'earth' to 'balance', or flexible bellows caged in flexures to take the axial force. One rig had the weight of the piping supported on an expanded polystyrene float in a bath of mercury.

The first model to be tested in the tunnel was a 1/5 scale Trident half-model (see below), to investigate disturbed flow over the flaps due to flap tracks, jacks and de-icing pipes. These tests started on 18 March 1965.

Adjacent to the V/STOL tunnel was a vacuum pump house with an 18in vacuum line running diagonally up the side of the tunnel to the working section. It consisted of three 250hp liquid ring rotary pumps, installed for the civil V/STOL programme to provide intake flow on models. This plant was very impressive as at the low vacuum values, it could match the mass flow from the Halford Laboratory compressors. When the V/STOL programme collapsed, it received very little use, except for a period of testing missile intakes for Dynamics as well as the 146-57 isolated pod model. Borne out of the problems associated with the first HS 133 fan model in trying to get everything to work and calibrated without taking up valuable running time for other models, a static test facility was erected adjacent to the vacuum pump house. This consisted of an open steel framework duplicating the structure and geometry of the V/STOL tunnel working section at full-scale. It was built for the civil V/STOL programme in 1970, and included a representation of the balance superstructure, with turntable for sideslip motion. It had the full compressed air and vacuum services of the V/STOL tunnel and was used for calibration and shake-down tests to ensure that model intake suction, engine pod blowing or pressure testing were all working satisfactorily prior to installing the model in the tunnel. Unfortunately, the civil V/STOL programme came to an end in 1974, and after that this facility was under-utilised. Shake-down tests carried out in the static test house and subsequent testing in the tunnel between 1969 and 1975 included the following V/STOL and STOL civil airliner research models:

- 1/14 scale HS 133 Interference complete model with two different wing plan-forms having ten Dowty /Rotol tip turbine fans, under test during 1967. Model manufactured at Hatfield
- 1/14 scale HS 141 (C.11) complete model multi-engine injector type with 16 injector units arranged in sponsons along the fuselage side. Wing span 5.38ft & length 7.8ft – July 1970. Model manufactured at Brough
- 1/10.53 scale HS 141 (C.12) complete model multi-engine fan model with 16 Tech Development turbine fans to simulate lift engines, arranged in sponsons along the fuselage side. A typical fan was driven by high pressure air fed to a single stage, multi-bladed axial tip turbine ring. The model was similar but larger than C.11 and was primarily designed for testing in the Canadian NRC 30ft tunnel in Ottawa but was also tested in the 15ft tunnel (August 1971). Span 7.19ft and length 11.3ft. Model manufactured at Hatfield
- C.19 originally a 4-injector model that could be converted to 2 injectors (complete model)
- C.20 (M901) pod jet flap model

- C.21 Budworth Trident was a hybrid model formed by the combination of the modified Trident 1/5 scale half-model and a Budworth 12-inch diameter fan. The fan was located at the inboard trailing edge of the wing and set within a sponson, it could swivel within the range 30 forward to 35 degrees aft in addition to the normal model incidence range. The half-model could easily revert to its normal Trident configuration. Budworth Trident testing took place during 1974.

Other projects tested in the V/STOL tunnel were as follows:

- HS 146 57 Pod
- 3/20 scale Kestrel / Harrier complete model 1964.

All the blown tunnel testing on Kestrel / Harrier models, from the start of the project to the end of the development of the type, was carried out in the Hatfield V/STOL tunnel. The Wind Tunnel Department was very proud of its contribution to that remarkable aeroplane, and looked forward to continuing with the 'Three-legged Stool' as the P1216 was irreverently dubbed, but it was not to be.

The last test series in the 15ft tunnel (note that following the collapse of the civil V/STOL programme, it was referred to as the 15ft tunnel) was on a 1/8 scale ATP complete model, and the tunnel was run for the last time on 21 July 1992. The balance was removed to Manchester University in January 1993 and the tunnel itself was then demolished.

Plate 24: The V/STOL tunnel (centre) with No.25 (Gyron) test bed in the foreground while at the top of the picture is the engine company Halford Laboratory. The open-return nature of the tunnel design can clearly be seen. The intake screen can be seen far left, followed by the intake and contraction. The working section follows this inside the brick building, then a short transition section, followed by a long diffuser and then another small transition section. The final parts are the fan section and the open exit screen on the extreme right. Photo taken in 1965, before the static test facility was built.

Plate 25: HS 133 an early V/STOL airliner configuration

Plate 26: HS 141 C.12 complete model with tufts positioned on the wings and sponsons which would be filmed by an 8 mm cine camera to determine the airflow pattern over the control surfaces. Generally, there were four main flow conditions during a typical run, these consisted of, steady and smooth, unsteady, rough and, stalled flow.

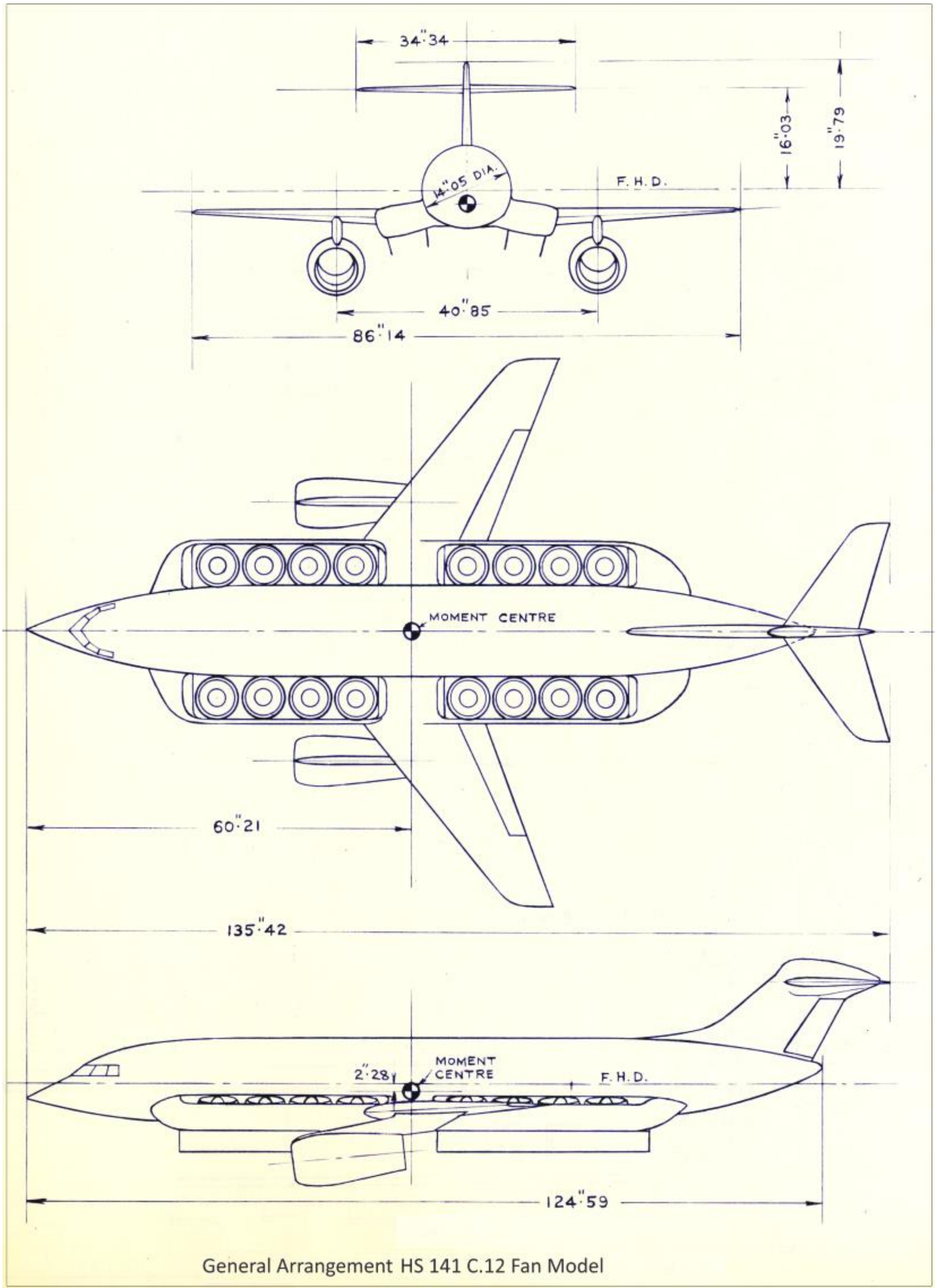

Fig.3: Drawing of HS 141, C.12 model

Plate 27: Jetstream 41 complete model mounted on three struts c.1990

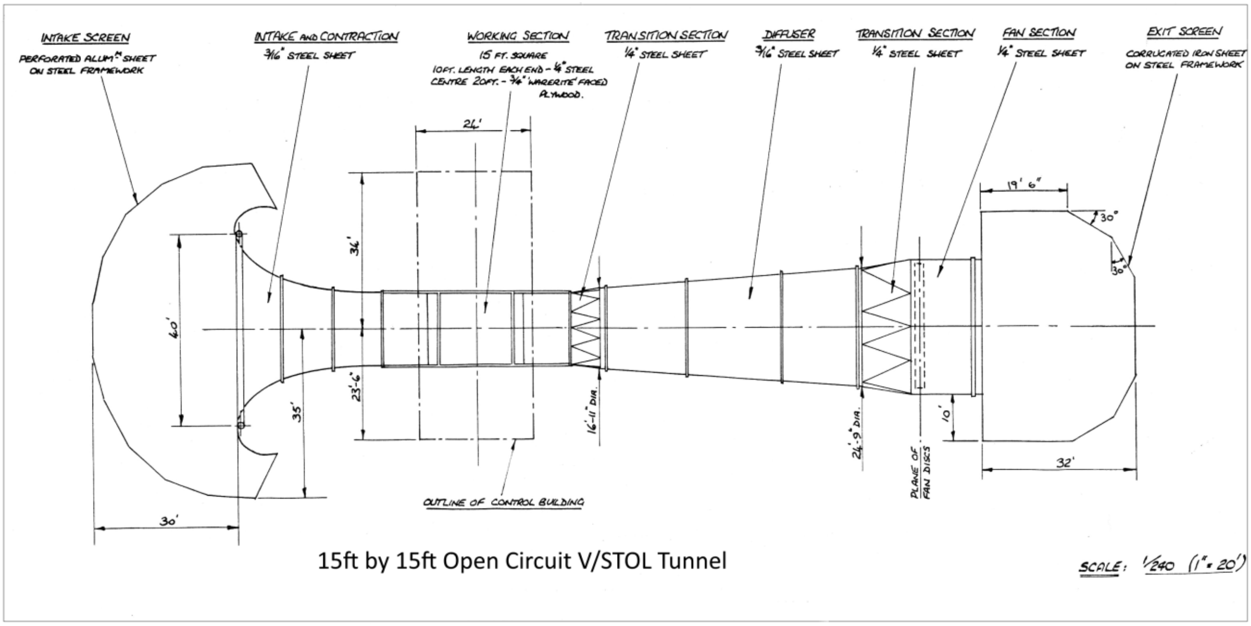

Fig. 4: Diagram of V/STOL Tunnel

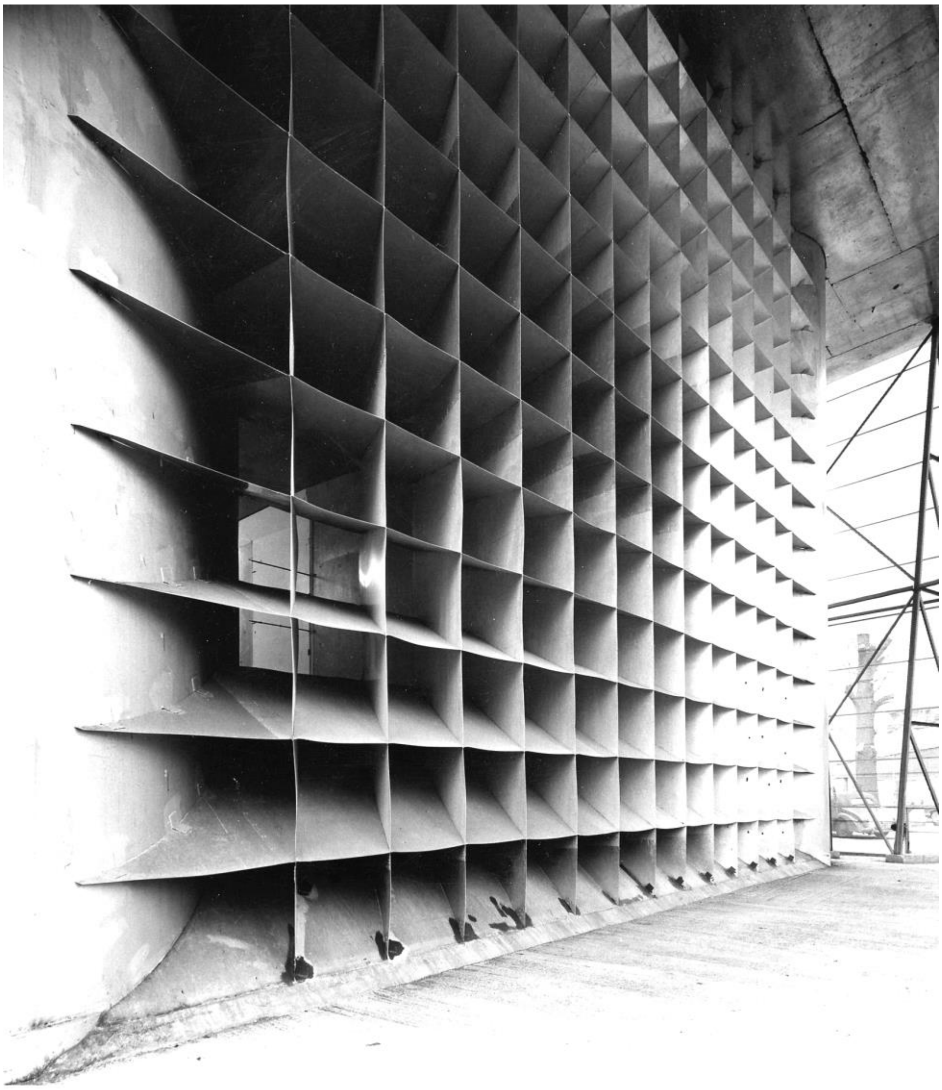

Plate 28: Air entry honeycomb

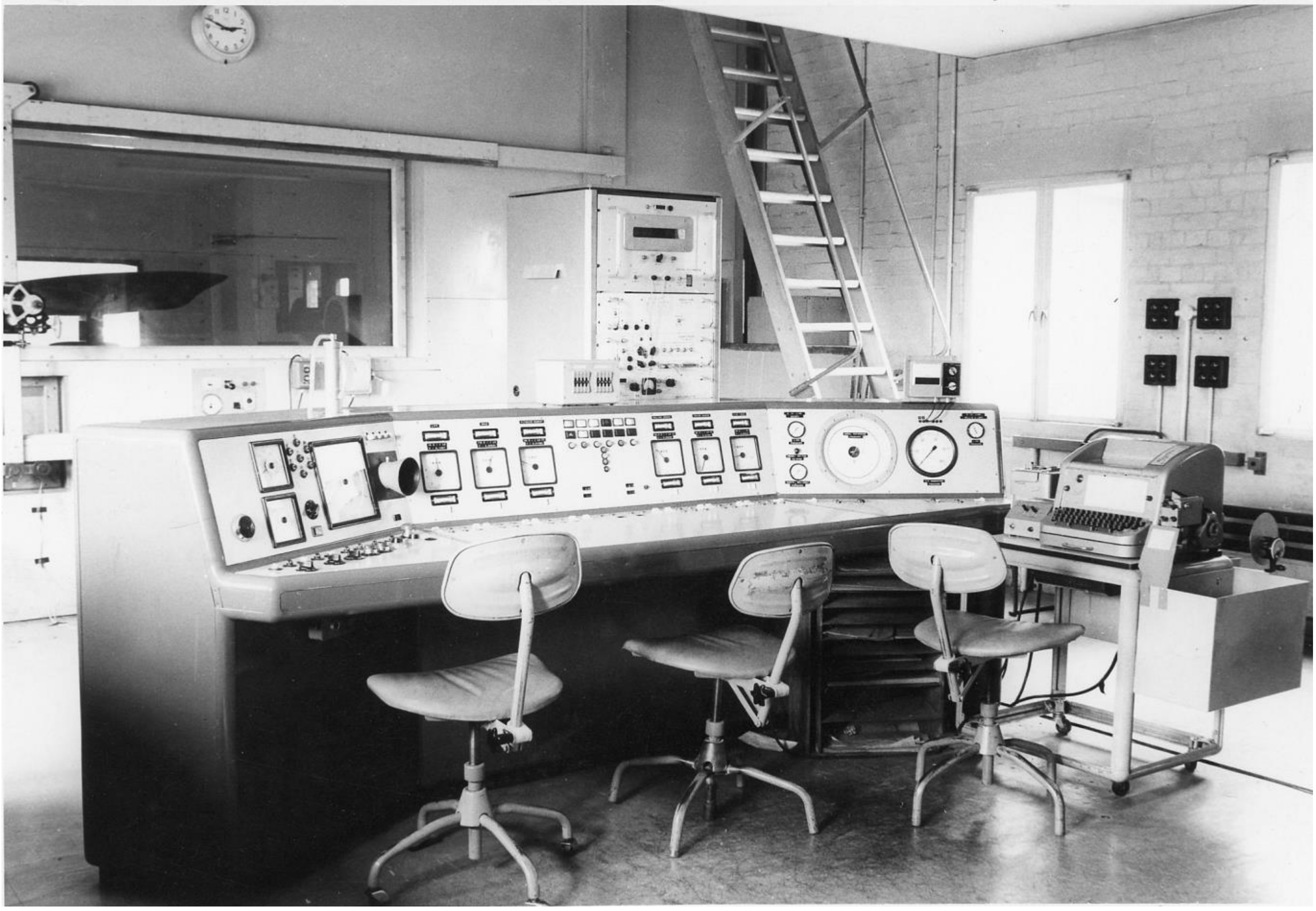
Plate 29: The V/STOL tunnel control room, photo believed to have been taken shortly after commissioning

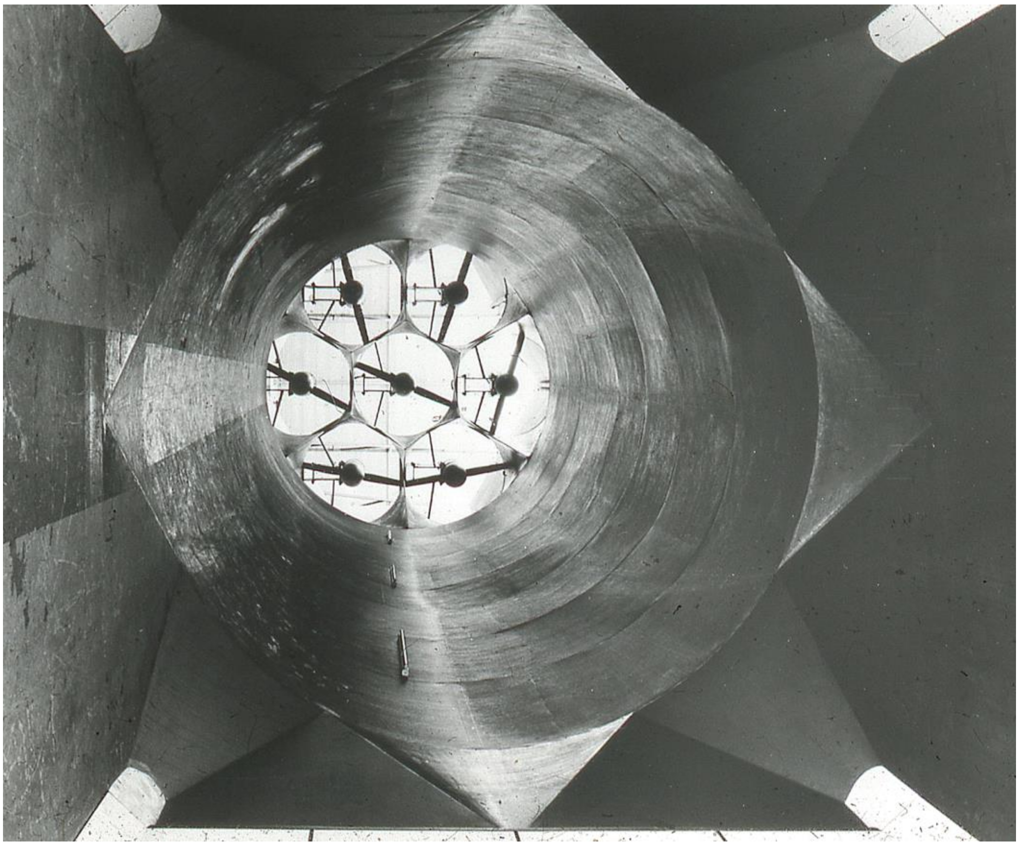
Plate 30: The steel structure of the V/STOL tunnel diffuser looking towards the fan section. Photo taken during construction

Plate 31: Kestrel / Harrier complete model rigged inside the static test facility adjacent to the V/STOL tunnel c.1970

Plate 32: 15ft Tunnel 1990

Plate 33: Another view of the 15ft Tunnel 1990

Part 4: Vibration / Noise Rig

Built in 1989 and located on a remote site accessed from the northern perimeter track, was a vibration / noise research facility that was managed by the wind tunnel department. It consisted of a large low speed wind tunnel to simulate forward flight and to relieve tip-stresses on the rotating propellers, a centre section of an old BAE 146 fuselage and, a Double Mamba engine change unit mounted onto a rigid frame within a fenced compound. Other parts included a control room, workshop and a vibration test facility caravan with monitoring equipment.

Its purpose was to determine the value of interior furniture and fittings to dampen out vibration from the counter rotating propellers. Tests were therefore carried out firstly with an empty cabin devoid of all fittings, including carpet, seats, luggage racks and interior wall and ceilings. One by one these were re-fitted and several engine runs were carried out each time to determine a fitting's contribution to dampen out vibration at different positions within the length of the cabin. Measurements were taken inside by a vibrometer array once the propellers had synchronised as indicated by a pair of lasers to determine the position of a target fitted to either propeller hub relative to each other. The project was completed on 24 December 1993 and the rig was demolished shortly after.

Plate 34: The Double Mamba ECU. The data recording caravan can be seen in the background

Plate 35: A view of the vibration / noise rig showing the Double Mamba with propellers rotating

Plate 36: Another view of the rig running

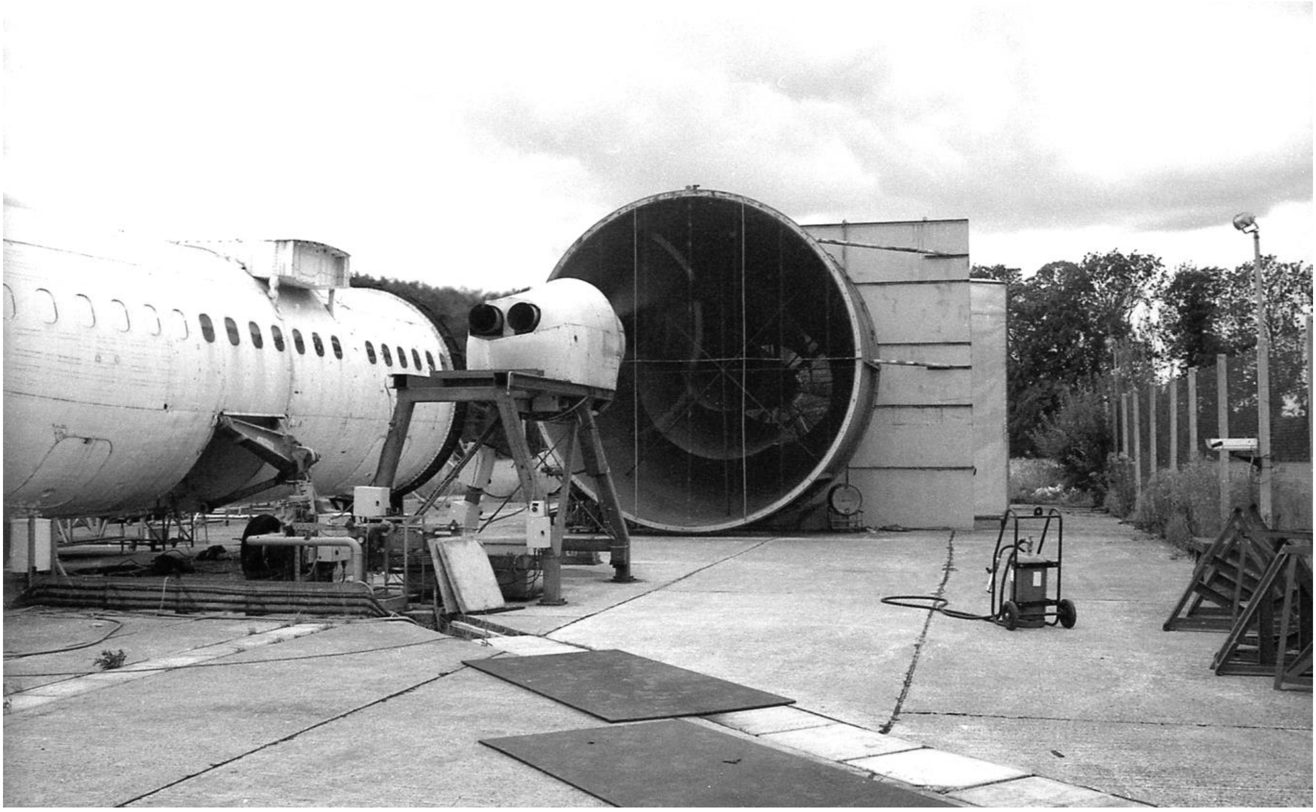

Plate 35: The wind tunnel (forward flight simulator) running

Plate 36: Fuel installation and spare BAE 146 and ATP fuselages

ARG Archives, Archive Box # 5: Hatfield Wind Tunnels Photos (box also contains photos from many other wind tunnels)				
Ascension Number	*Description*	*Date*	*Owner*	*Cond.*
09-2011PB29-271	Wing model in LSWT	No date	PF	1
09-2011PB29-272	Kingston model	No date	PF	1
09-2011PB29-273	4 images of half-model in LSWT	No date	PF	1
09-2011PB29-274	BAE 146 early half model	No date	PF	1
09-2011PB29-275	Trident model in HSWT	No date	PF	1
09-2011PB29-276	Trident engine nacelle model in HSWT	No date	PF	1
09-2011PB29-277	Trident Schliern picture	No date	PF	1
09-2011PB29-278	Trident model in LSWT	No date	PF	1
09-2011PB29-279	Trident model in LSWT	No date	PF	1
09-2011PB29-280	'T' tail model in HSWT	No date	PF	1
09-2011PB29-281	Trident in LSWT (4 images)	No date	PF	1
09-2011PB29-282	VSTOL Tunnel view looking towards fans	No date	PF	1
09-2011PB29-283	Fan blade installation in LSWT	No date	PF	1
09-2011PB29-284	Early Calculator	No date	PF	1
09-2011PB29-285	2-D model in LSWT	No date	PF	1
09-2011PB29-286	2-D model in LSWT	No date	PF	1
09-2011PB29-287	HS VSTOL Airliner in VSTOL Tunnel	No date	PF	1
09-2011PB29-288	HS VSTOL Airliner in VSTOL tunnel	No date	PF	1
09-2011PB29-289	HS VSTOL Airliner in VSTOL tunnel	No date	PF	1
09-2011PB29-290	HS VSTOL airliner model in VSTOL Tunnel	No date	PF	1
09-2011PB29-291	HS VSTOL airliner model in VSTOL Tunnel	No date	PF	1
09-2011PB29-292	HS VSTOL airliner model in VSTOL Tunnel	No date	PF	1
09-2011PB29-293	HS VSTOL airliner close-up of sting	No date	PF	1
09-2011PB29-294	VSTOL half model with blown rotor (2 images) in LSWT	No date	PF	1
09-2011PB29-295	VSTOL half model with blown rotor (2 images) in LSWT	No date	PF	1
09-2011PB29-296	VSTOL half model with blown rotor (2 images) in LSWT	No date	PF	1
09-2011PB29-297	VSTOL half model with blown rotor (2 images) in LSWT	No date	PF	1
09-2011PB29-298	VSTOL half model with blown rotor (3 images) in LSWT	No date	PF	1
09-2011PB29-299	VSTOL half model with blown rotor (4 images) in LSWT	No date	PF	1
09-2011PB29-300	VSTOL half model with blown rotor (4 images) in LSWT	No date	PF	1
09-2011PB29-301	VSTOL half model with blown rotor (3 images) in LSWT	No date	PF	1
09-2011PB29-302	VSTOL half model with blown rotor (4 images) in LSWT	No date	PF	1
09-2011PB29-303	HS 125 in LSWT	No date	PF	1
09-2011PB29-304	Model Shop wing leading edge being worked on (2 copies)	No date	PF	1
09-2011PB29-305	Model Shop NC Machining (2 copies)	No date	PF	1
09-2011PB29-306	Model Shop milling machine	No date	PF	1
09-2011PB29-307	Model shop staff with Jetstream fin and tail	No date	PF	1
09-2011PB29-308	BAE 146 with oil flow model yawed in LSWT	No date	PF	1
09-2011PB29-309	Boat model with Paul Francis on ground board in LSWT	No date	PF	1
09-2011PB29-310	Nimrod half-model in LSWT	No date	PF	1
09-2011PB29-311	Nimrod half-model in LSWT	No date	PF	1
09-2011PB29-312	Nimrod half-model	No date	PF	1
09-2011PB29-313	Nimrod Half-model in LSWT	No date	PF	1
09-2011PB29-314	Nimrod half model in LSWT	No date	PF	1
09-2011PB29-315	Wind Tunnel contraction	No date	PF	1
09-2011PB29-316	Airbus in LSWT	No date	PF	1

09-2011PB29-317	Half model in LSWT (2 copies)	No date	PF	1
09-2011PB29-318	Early A300 model in LSWT	No date	PF	1
09-2011PB29-319	A300 half-mode in LSWT	No date	PF	1
09-2011PB29-320	Airbus in LSWT	No date	PF	1
09-2011PB29-321	Airbus in VSTOL	No date	PF	1
09-2011PB29-322	Airbus model rotating on ground board inside VSTOL tunnel	No date	PF	1
09-2011PB29-323	Airbus model in VSTOL tunnel	No date	PF	1
09-2011PB29-324	Airbus half model on ground board with smoke	No date	PF	1
09-2011PB29-325	Airbus model with engine efflux rig in LSWT	No date	PF	1
09-2011PB29-326	Airbus model in LSWT (4 images)	No date	PF	1
09-2011PB29-327	Airbus model in LSWT (3 images)	No date	PF	1
09-2011PB29-328	Airbus model on ground board in VSTOL tunnel	No date	PF	1
09-2011PB29-329	VSTOL Tunnel	No date	PF	1
09-2011PB29-330	Balance Schematic	No date	PF	1
09-2011PB29-331	Propeller Tunnel under construction	28-07-53	PF	1
09-2011PB29-332	146-56 1:4.5 Scale half-model in VSTOL Tunnel	No date	PF	1
09-2011PB29-333	2-D model in LSWT (2 copies)	No date	PF	1
09-2011PB29-334	2-D model in LSWT	No date	PF	1
09-2011PB29-335	Jetstream model in Model Shop	No date	PF	1
09-2011PB29-336	Jetstream model in VSTOL Tunnel	No date	PF	1
09-2011PB29-337	Jetstream in VSTOL tunnel being worked on	No date	PF	1
09-2011PB29-338	Jetstream wing NC machining	No date	PF	1
09-2011PB29-339	Jetstream in VSTOL tunnel	No date	PF	1
09-2011PB29-340	Jetstream model in transport stand	No date	PF	1
09-2011PB29-341	Jetstream in VSTOL tunnel	No date	PF	1
09-2011PB29-342	Jetstream wing being NC machined	No date	PF	1
09-2011PB29-343	Jetstream in VSTOL tunnel (2 copies)	No date	PF	1
09-2011PB29-344	2 images of actuators mounted on a sting	No date	PF	1
09-2011PB29-345	Wing model in LSWT	No date	PF	1
09-2011PB29-346	Wind Tunnel dept. newly complete interior of WT room ?	21-01-54	PF	1
09-2011PB29-347	Model of VSTOL tunnel (6 images)	No date	PF	1
09-2011PB29-348	Model of VSTOL tunnel (6 images)	No date	PF	1
09-2011PB29-349	Contraction of HSWT	No date	PF	1
09-2011PB29-350	HS VSTOL airliner close-up of sting	No date	PF	1
09-2011PB29-351	Working Harrier model in VSTOL tunnel	No date	PF	1
09-2011PB29-352	Static Rig Shop view from outside	No date	PF	1
09-2011PB29-353	Model shop	10-11-54	PF	1
09-2011PB29-354	HS 136 1/14th scale with oil flow (3 images)	No date	PF	1
09-2011PB29-355	HS 136 1/14th scale model in LSWT (3 images)	No date	PF	1
09-2011PB29-356	HS 136 1/14th scale model in LSWT (3 images)	No date	PF	1
09-2011PB29-357	HS 136 1/14th scale model in LSWT (3 images)	No date	PF	1
09-2011PB29-358	HS 136 1/14th scale model in LSWT (3 images)	No date	PF	1
09-2011PB29-359	HS 136 1/14th scale model in LSWT (3 images)	No date	PF	1
09-2011PB29-360	HS 1182 Half model on ground board in VSTOL tunnel	23-01-70	PF	1
09-2011PB29-361	HS 1182 Half model on ground board in VSTOL tunnel	23-01-70	PF	1
09-2011PB29-362	HS 1182 Half model on ground board in VSTOL tunnel	23-01-70	PF	1
09-2011PB29-363	HS 1182 Half model on ground board in VSTOL tunnel	16-02-70	PF	1
09-2011PB29-364	HS 1182 Half model on ground board in VSTOL tunnel	16-02-70	PF	1

09-2011PB29-365	HS 1182 Half model on ground board in VSTOL tunnel	16-02-70	PF	1
09-2011PB29-366	HS 1182 Half model on ground board in VSTOL tunnel	16-02-70	PF	1
09-2011PB29-367	HS 1182 Half model on ground board in VSTOL tunnel	No date	PF	1
09-2011PB29-368	HS 1182 Half model on ground board in VSTOL tunnel	No date	PF	1
09-2011PB29-369	HS 1182 Half model on ground board in VSTOL tunnel (2 images)	No date	PF	1
09-2011PB29-370	HS 1182 Half model on ground board in VSTOL tunnel	No date	PF	1
09-2011PB29-371	Harrier close-up inside VSTL tunnel	No date	PF	1
09-2011PB29-372	Drawing of VSTOL tunnel	No date	PF	1
09-2011PB29-373	Model of VSTOL tunnel	No date	PF	1
09-2011PB29-374	Unknown model in VSTOL tunnel	No date	PF	1
09-2011PB29-375	Wind Tunnel personnel inside VSTOL tunnel	No date	PF	1
09-2011PB29-376	Harrier fin close-up inside VSTOL tunnel (2 images)	No date	PF	1
09-2011PB29-377	Unknown model in LSWT (3 images)	No date	PF	1
09-2011PB29-378	Buccaneer half model on ground board inside VSTOL tunnel	No date	PF	1
09-2011PB29-379	Buccaneer 1/5 scale half-model in VSTOL tunnel	No date	PF	1
File # 6: Hatfield Wind Tunnels Negs, Slides and Prints				
09-2011PB29-380	17 colour 35 mm slides of A330/A340 possible ARA HSWT	No date	PF	1
09-2011PB29-381	4, 2 ¼ square negs of A330/A340 in VSTOL tunnel	No date	PF	1
09-2011PB29-382	6, 2 ¼ square negs and 6 en-prints of A330 / A240 in ARA HSWT	No date	PF	1
09-2011PB29-383	6, 2 ¼ square negs and 6 en-prints of A330 / A340 inside ARA HSWT	No date	PF	1
09-2011PB29-384	4, 2 ¼ square negs of A330 / A340 in VSTOL tunnel	No date	PF	1
09-2011PB29-385	4, 35 mm slides of Hatfield HSWT	No date	PF	1
09-2011PB29-386	4, 2 ¼ square negs of A330 / A340 in VSTOL tunnel	No date	PF	1
09-2011PB29-387	4, 2 ¼ square negs of A330 / A340 in VSTOL tunnel	No date	PF	1
09-2011PB29-388	4, 2 ¼ square negs of A330 / A340 in VSTOL tunnel	No date	PF	1
09-2011PB29-389	4, 2 ¼ square negs of A330 / A340 in VSTOL tunnel plus 1 in ARA HSWT	No date	PF	1
09-2011PB29-390	4, 2 ¼ square negs of A330 / A340 in VSTOL tunnel	No date	PF	1
09-2011PB29-391	4, 2 ¼ square negs of VSTOL tunnel models	No date	PF	1
09-2011PB29-392	4, 2 ¼ square negs of A330 / A340 in VSTOL tunnel	No date	PF	1
09-2011PB29-393	4, 2 ¼ square negs of A330 / A340 in VSTOL tunnel plus 4 trident model negs in VSTOL	No date	PF	1
09-2011PB29-394	4, 2 ¼ in square negs of models in VSTOL tunnel	No date	PF	1
09-2011PB29-395	5, 35 mm slides inside Hatfield wind tunnels	No date	PF	1
09-2011PB29-396	5, 35 mm slides inside Hatfield wind tunnels	No date	PF	1
09-2011PB29-397	1, 2 ¼ neg of HS VSTOL airliner in VSTOL tunnel plus 4 Trident images inside Hatfield HSWT	No date	PF	1
09-2011PB29-398	14 mounted 35 mm slides of Hatfield wind tunnels	No date	PF	1
09-2011PB29-399	3 similar slides of Jetstream in model shop and one slide of unknown model plus 3 negs of same	No date	PF	1
09-2011PB29-400	4, slides of Hatfield wind tunnels and models plus 3, 35 mm negs of personnel	No date	PF	1
File # 7: Hatfield Wind Tunnels Glass Slides				
09-2011PB29-401	Schliren	No date	PF	1
09-2011PB29-402	Gyron Junior on test bed, Comet Wing	No date	PF	1
09-2011PB29-403	LSWT Drawing and Comet model	No date	PF	1
09-2011PB29-404	Comet half-model and Schliren	No date	PF	1
09-2011PB29-405	Interior of HSWT and Drawing of HSWT	No date	PF	1
09-2011PB29-406	HSWT drawing of working section and Comet model in workshop	No date	PF	1
09-2011PB29-407	Flight corridor schematic	No date	PF	1
09-2011PB29-408	Drawing of proposed wind tunnel	No date	PF	1
09-2011PB29-409	Temperature graph and Schliren	No date	PF	1

ARG Archives, Archive Box # 26: Correspondence to and from the Wind Tunnel Department (box also contains letters concerning other BAE sites)				
06-2012PB26-101	Correspondence concerning the construction and fitting out of the de Havilland HSWT	1952-1954	PF	2
06-2012PB26-102	James Gordon & Co Ltd	29-05-52	PF	2
06-2012PB26-103	James Monro & Son charted architects (10 letters)	03-07-53	PF	2
06-2012PB26-104	Optical Works Ltd	22-07-53	PF	2
06-2012PB26-105	Minimax Limited (3 letters)	29-07-53	PF	2
06-2012PB26-106	The Airscrew Company & Jicwood Ltd (5 letters)	01-09-53	PF	2
06-2012PB26-107	Flexo Plywood Industries Ltd, South Chingford, letters and exchange of notes with James Monro & Son	09-11-53	PF	2
06-2012PB26-108	Flexo Wood Industries	10-11-53	PF	2
06-2012PB26-109	Burgess Products Company Ltd (5 letters)	08-12-53	PF	2
06-2012PB26-110	Gardiner Sons & Co Ltd	05-01-54	PF	2
06-2012PB26-111	Cementation (Muffelite) Limited (1 letter)	01-02-54	PF	2
06-2012PB26-112	Sunvic Controls Ltd	09-02-54	PF	2
06-2012PB26-113	Gilbert Ash	11-05-54	PF	2
06-2012PB26-114	J Stone & Company (Charlton) Ltd	24-06-54	PF	2
06-2012PB26-115	Semtex Ltd	10-01-55	PF	2
06-2012PB26-116	William Mallinson & Sons Ltd	10-05-55	PF	2
06-2012PB26-117	William Mallinson & Sons Ltd quotation	27-05-55	PF	2
06-2012PB26-118	Lintronic Limited	17-08-55	PF	2
06-2012PB26-119	Burgess Products Company Ltd	09-09-55	PF	2
06-2012PB26-120	University of Cambridge Department of Engineering (2 letters)	15-11-55	PF	2
06-2012PB26-121	Cementation (Muffelite) Limited, (5 letters)	04-10-55	PF	2
06-2012PB26-122	Pilkington Brothers Ltd (6 letters)	23-11-55	PF	2
06-2012PB26-123	Rothampstead Experimental Station (3 letters)	26-11-55	PF	2
06-2012PB26-124	Ultra Electric Limited (2 letters)	02-01-56	PF	2
06-2012PB26-125	Sandvik Swedish Steels Ltd (letter & order note)	12-01-56	PF	2
06-2012PB26-126	Underwood Business Machines, Ltd (3 letters)	13-02-56	PF	2
06-2012PB26-127	Ross Brothers	09-04-56	PF	2
06-2012PB26-128	Ernest Turner Electrical Instruments Ltd	29-05-56	PF	2
06-2012PB26-129	Towler & Son Limited	06-06-56	PF	2
06-2012PB26-130	Newall Group Sales Ltd (2 letters & 2 despatch notes)	17-07-56	PF	2
06-2012PB26-131	Midland Silicones Limited	19-07-56	PF	2
06-2012PB26-132	CC Wakfield & Co Ltd (5 letters)	19-07-56	PF	2
06-2012PB26-133	Shell-Mex and BP Ltd (2 letters)	23-07-56	PF	2
06-2012PB26-134	Mechanism Limited	14-09-56	PF	2
06-2012PB26-135	John Oakley & Sons Ltd (2 letters & sample)	09-11-56	PF	2
06-2012PB26-136	The Micanite & Insulators Co Ltd (3 letters)	18-12-56	PF	2
06-2012PB26-137	Optical Measuring Tools Ltd (letter & delivery note)	14-01-57	PF	2
06-2012PB26-138	Whessoe Limited	08-03-57	PF	2
06-2012PB26-139	Neville Brown and Company Ltd (3 letters)	04-03-57	PF	2
06-2012PB26-140	Norton Grinding Wheel Co Ltd (2 letters)	25-03-57	PF	2
06-2012PB26-141	George W Rawlings & Partners Limited	21-06-57	PF	2
06-2012PB26-142	Winston Electronics (3 letters)	27-05-57	PF	2
06-2012PB26-143	Newall Engineering Co Ltd (5 letters)	09-07-57	PF	2
06-2012PB26-144	Wails Dove Bitumastic Limited	10-07-57	PF	2
06-2012PB26-145	The Motor Industry Research Association (2 letters)	12-08-57	PF	2

06-2012PB26-146	Sangamo Weston Limited	30-09-57	PF	2
06-2012PB26-147	Studio Jeunesse Sales Dept	16-12-57	PF	2
06-2012PB26-148	Newall Engineering Co Ltd	02-01-58	PF	2
06-2012PB26-149	Northern Aluminium Company Ltd despatch note	16-04-58	PF	2
06-2012PB26-150	West London Optical Tool Company Ltd (letter & photo)	17-06-58	PF	2
06-2012PB26-151	Scott Bader & Co Ltd	17-07-58	PF	2
06-2012PB26-152	Solartron Electronic Group Ltd	30-07-58	PF	2
06-2012PB26-153	The Turnbridge MFG & Supply Co Ltd	15-09-58	PF	2
06-2012PB26-154	Marconi’s Wireless Telegraph Company Limited	05-11-58	PF	2
06-2012PB26-155	George Winnal & Son Limited	05-01-59	PF	2
06-2012PB26-156	Ingersoll-Rand proposal	21-04-61	PF	2
06-2012PB26-157	The Expanded Metal Company	10-10-61	PF	2
06-2012PB26-158	Broom & Wade Limited (tender)	21-09-62	PF	2
06-2012PB26-159	Westool Ltd	26-06-63	PF	2
06-2012PB26-160	Electrical Surplus	25-06-63	PF	2
06-2012PB26-161	RR Britton Ltd	27-06-63	PF	2
06-2012PB26-162	David Brown Corporation (sales) Limited	28-06-63	PF	2
06-2012PB26-163	Associated Electrical Industries Limited (letter & curve)	15-07-63	PF	2
06-2012PB26-164	Harleys (Stoke-on-Trent) Ltd (3 letters)	07-10-63	PF	2
06-2012PB26-165	The Capper Pipe Service Ltd	29-10-63	PF	2
06-2012PB26-166	J Blackeborough & Sons Ltd	28-11-63	PF	2
06-2012PB26-167	Crosby Valve & Engineering Co Ltd (2 letters)	17-12-63	PF	2
06-2012PB26-168	Grosvenor Plumbing & Heating Ltd (2 letters)	09-01-64	PF	2
06-2012PB26-169	Gloucester Controls Limited (2 letters)	21-01-64	PF	2
06-2012PB26-170	Honeywell Controls Ltd	23-03-64	PF	2
06-2012PB26-171	Microponent Development Ltd	10-04-64	PF	2
06-2012PB26-173	Vokes Limited	04-11-64	PF	2
06-2012PB26-174	Henry Simon Limited	11-12-64	PF	2
06-2012PB26-175	TEM Engineering Limited	07-01-65	PF	2
06-2012PB26-176	CIBA (ARL) Limited	27-07-65	PF	2
06-2012PB26-177	G&E Bradley Ltd	20-09-65	PF	2
06-2012PB26-178	Begg, Cousland & Co Ltd	10-06-66	PF	2
06-2012PB26-179	Lancaster & Tonge Ltd (letter & estimate)	03-01-67	PF	2
06-2012PB26-180	Halse & Marshall certificates	04-12-68	PF	2
06-2012PB26-181	Hewlett Packard	25-09-69	PF	2
06-2012PB26-182	CH Johnson & Sons Ltd (2 letters)	09-09-70	PF	2
06-2012PB26-183	English Electric-AEI Machines Limited	24-05-71	PF	2
06-2012PB26-184	United Wire Ltd	24-08-71	PF	2
06-2012PB26-185	Hick Hargreaves & Co Ltd	18-11-71	PF	2
06-2012PB26-186	Harvey Fabrication Limited	17-05-72	PF	2
06-2012PB26-187	Siston Metals Limited	05-04-73	PF	2
06-2012PB26-188	Semon Shotblast Co Ltd	04-06-74	PF	2
06-2012PB26-189	Godfrey Engineering Limited	11-06-73	PF	2
06-2012PB26-190	Staravia Limited certificate	10-12-80	PF	2
06-2012PB26-191	Deritend Electrical Service Ltd	18-05-81	PF	2
06-2012PB26-192	British Steel Corporation Sheffield Laboratories	25-03-81	PF	2
06-2012PB26-193	GEC Electrical Projects Limited	20-07-81	PF	2
06-2012PB26-194	HM Customs and Excise (2 letters)	12-05-82	PF	2

06-2012PB26-195	Webb Harris	21-02-83	PF	2
06-2012PB26-196	TI Flexible Tubes Ltd	16-02-84	PF	2
06-2012PB26-197	Royles Limited letter & test certificate	13-04-73	PF	2
06-2012PB26-198	Plastic Constructions plc	20-08-85	PF	2

ARG Archives, Archive Box # 32: Wind Tunnel Reports (box also contains reports from other facilities)				
06-2012PB32-13	Folder: de Havilland Wind Tunnel Design – Based on English Electric Experience	1951	PF	2
06-2012PB32-14	Report: de Havilland Wind Tunnel Note 460: HSWT Wall Constraint Corrections – Transonic Liners	29-06-62	PF	2
06-2012PB32-22	Sir Howard Grubb, Parsons & Co Aerodynamic Balance for RAE HSWT	1942	PF	2

ARG Archives, Archive Box # 40: Wind Tunnel Data (box also contains many other reports from various facilities)				
Hatfield Reports and Drawings				
06-2012PB40-1	De Havilland Aircraft Co Details of Wind Tunnels	1955	PF	2
06-2012PB40-2	Drag Repeatability 15ft Tunnel	1972	PF	2
06-2012PB40-3	Wind Tunnel Memo Comments on Possible Upwash in the 15ft Wind Tunnel Test Section	c.1972	PF	2
06-2012PB40-4	C.12 Fan Interference Model Test Programme for 2nd Test Series in 15ft WT	1971	PF	3
06-2012PB40-5	C.12 Fan-Powered Interference Model Fan Operating Procedures for the 2nd Test Series in the 15ft WT	1971	PF	3
06-2012PB40-6	Wind Tunnel Research Models ‘C’ Series – General Description photocopy	1971	PF	3
06-2012PB40-7	New de Havilland High Speed Wind Tunnel Exhaust Noise Silenced by Cementation (Muffelite) Limited – General Description	c.1953	PF	3
06-2012PB40-8	Grubb-Parsons Virtual Centre Air-Bearing Balance for de Havilland 15ft V/STOL Wind Tunnel specification	undated	PF	3
06-2012PB40-9	Interim Report on the Operational Status of the 15ft V/STOL Tunnel	1965	PF	3
06-2012PB40-10	HS Harrier T Mk.2, 3/20 Scale LS Model Programme of WT Tests to Investigate the V/STOL Sideslip Problem	1969	PF	3
06-2012PB40-11	Hawker Siddeley Aviation Ltd HS 121 1/46th Scale P2 Rear End Model in the Transonic 2 by 2ft 5 in Tunnel	1976	PF	3
06-2012PB40-12	Alternative Proposals for a HSWT at Hatfield	1970	PF	3
06-2012PB40-13	V/STOL Tunnel Design intake specification	undated	PF	3
06-2012PB40-14	Hawker Siddeley Aviation Ltd Installation of HS 141, C.12 Fan Model	1971	PF	3
06-2012PB40-15	Provisional Test Programme for the 1st Test Series of the C.11 Injector Model	1970	PF	3
06-2012PB40-16	Proposals for Modifying and Overhauling the Hatfield 2.5ft by 2ft High Speed Wind Tunnel	1970	PF	2
06-2012PB40-17	Hawker Siddeley Aviation Ltd Hatfield Wind Tunnel Facilities	1972	PF	2
06-2012PB40-18	Notes on a Talk by JA Kirk on Wind Tunnels	undated	PF	2
06-2012PB40-19	Hawker Siddeley Aviation Schemes for Modifying the High-Speed Wind Tunnel	1970	PF	2
06-2012PB40-20	Disadvantages of using Manchester or Brough High Speed Wind Tunnels	1970	PF	
06-2012PB40-21	C.21 Wind Tunnel Programme	1972	PF	2
06-2012PB40-22	The Low Speed Wind Tunnel – a Talk by BG Cox	1967	PF	
06-2012PB40-23	VSTOL Tunnel Description (front cover / page 1 missing)	c.1972	PF	2
06-2012PB40-24	History of Hatfield Wind Tunnels by Paul Francis (original)	1993	PF	2
06-2012PB40-25	Hawker Siddeley Aviation – Ghost Engines for High Speed Tunnel	1973	PF	2
06-2012PB40-26	Wind Tunnel Meeting Note: Research Items	1967	PF	2
06-2012PB40-27	Design of LSWT NPL Note AERO 1039 – Relevant to 15ft Tunnel	undated	PF	2
06-2012PB40-28	Instrument Laboratory Report	1971	PF	2
06-2012PB40-29	Wind Tunnel Note WTN 1080: HS 133/141 1/14 scale Interference Model 3rd Test Series	1969	PF	2
06-2012PB40-30	Wind Tunnel Note 1572: Programme for the 2nd Test Series of Tests on the C.19 Model in the 15ft LSWT	1971	PF	2

06-2012PB40-31	Wind Tunnel Meeting Note to Discuss Research Items	1967	PF	2
06-2012PB40-32	Plan of Proposed Dept. Extension	undated	PF	2
06-2012PB40-33	Plan of V/STOL Tunnel	1963	PF	2
06-2012PB40-34	Plan 1652/W/11 V/STOL Wind Tunnel Plans, Sections & Elevations	1963	PF	2
06-2012PB40-35	Wind Tunnel Model Shop (not complete)	undated	PF	2
06-2012PB40-36	15ft LSWT Comparison of Cost Estimates	1963	PF	2
06-2012PB40-37	Plan 1652/W/10: Location Plan	1963	PF	2
06-2012PB40-38	Wind Tunnel Model Storage	1978	PF	2
06-2012PB40-39	Proposed Extension to Model Shop	1964	PF	2
06-2012PB40-40	BWT 7374/C Plan: Proposed Storage Building	1978	PF	2
06-2012PB40-41	V/STOL Tunnel Index of Reports	1972	PF	2
06-2012PB40-42	Wind Tunnel Meeting Note to Discuss Research Items	1967	PF	2
06-2012PB40-43	Wind Tunnel Note 1355 1/14 scale HS.141 C.11 Injector Model	1971	PF	2
06-2012PB40-44	Wind Tunnel Note RFM/Memo/96/KRF C.12 Fan-Powered Interference Model	1972	PF	2
06-2012PB40-45	De Havilland Gazette #82: Two Wind Tunnels Built and Run in a Year	1954	PF	2
06-2012PB40-46	BWT 5089 V/STOL Tunnel Drawing	undated	PF	2
06-2012PB40-47	De Havilland Aircraft Co Ltd Wind Tunnel Note # 415: High Speed Wind Tunnel Tests on the DH 125 1/35 Scale Complete Model – Effect of Tailplane	1961	PF	2
06-2012PB40-48	De Havilland Aircraft Co Wind Tunnel Report # 98: Tests on the 1/13 scale Model of the DH 129 in the AV Roe Low Speed Wind Tunnel	1962	PF	2
06-2012PB40-49	De Havilland Aircraft Co Wind Tunnel Report # 97: Tests on the 1/13 scale model of the DH 129 made in the AV Roe Low Speed Wind Tunnel	1962	PF	2
06-2012PB40-50	Hawker Siddeley Aviation Ltd Hatfield Wind Tunnel Programme: C.12 Fan-Powered Interference Model 2nd Test Series in the Hatfield 15ft VSTOL Tunnel	1971	PF	2
06-2012PB40-51	Hawker Siddeley Aviation Ltd Hatfield Wind Tunnel Static Test House Note	1975	PF	2
06-2012PB40-52	Hawker Siddeley Aviation Ltd, Hatfield Wind Tunnel Report # 186: Preliminary Calibration of the HAS 15ft VSTOL Wind Tunnel by PA Champion	1965	PF	1
06-2012PB40-53	C.21-Budworth Trident 15ft Tunnel 1st Test Series Photographs Folder	1970s	PF	2
06-2012PB40-54	De Havilland Aircraft Co Ltd Wind Tunnel Note # 493: Tests on a 5 ¼ by 5 ¼ inch Open Return Circuit Wind Tunnel to Determine the Effect of External Winds on Conditions in the Working Section	1962	PF	1
06-2012PB40-55	A Wind Tunnel Engineer's Guide to Good Photography	1970s	PF	2
06-2012PB40-56	HS.141 CII Injector Mode -l Model Details Note File	1971	PF	2
06-2012PB40-57	De Havilland Aircraft Co High Speed Wind Tunnel Engine Installation Report	1962	PF	2
06-2012PB40-58	15ft Wind Tunnel Measurements	1973	PF	2
06-2012PB40-59	C.12 Fan-Powered Interference Model Programme for 2nd Test Series in the Hatfield 15ft Wind Tunnel	1971	PF	2
06-2012PB40-60	Large file on Proposed Wind Tunnels at Hatfield	1952	PF	2
06-2012PB40-61	Externally Blown Jet Flap Research Model details	1975	PF	1
06-2012PB40-62	File on Justification on Retaining HST	1969	PF	2
06-2012PB40-63	Wind Tunnel Note 482 LSWT Tests on a 1/7 scale Model B of the DH125	1962	PF	2
06-2012PB40-64	Wind Tunnel Note: C.21 Budworth Trident Model – A brief description of the model and instrumentation	1973	PF	2
06-2012PB40-65	Wind Tunnel Note: HS. 141 C.12 Multi-Fan Model Details	1974	PF	2
06-2012PB40-66	Wind Tunnel Research Models 'C' Series – General Information	1971	PF	2
06-2012PB40-67	Wind Tunnel Note: HS.141 Injector-Powered Interference Model C.11 Programme for 1st Test Series	1970	PF	2
06-2012PB40-68	Wind Tunnel Note WT N1358: High Speed Wind Tunnel Data Acquisition and Instrumentation	1971	PF	2
06-2012PB40-69	List of Reports in the Wind Tunnel Department (HSWT)	1971	PF	2
06-2012PB40-70	Report on Visit by R Webb to LSWT, Farnborough	1962	PF	2
06-2012PB40-71	Estimate and 2 drawings for proposed Model Shop Extension	1956	PF	2
06-2012PB40-72	Model Shop Note Prior to Extension	Undated	PF	2

06-2012PB40-73	Wind Tunnel Model Making	1956	PF	2
06-2012PB40-74	Wind Tunnel Memo: HSWT Complete Models on Sting Mounted Balances (hand-written)	undated	PF	2
06-2012PB40-75	Proposed Extension to Model Shop with estimate for new equipment	1956	PF	2
06-2012PB40-76	Book 3096/V: V/STOL Tunnel Flow Breakdown under Various Thrust-Lift Devices	1970	PF	2
06-2012PB40-77	Book 3165/V: C.21 Budworth Trident 15ft Tunnel 1st Test Series Photographs	undated	PF	2
06-2012PB40-78	Pylon The Journal of the HAS Apprentice Training Schools and the de Havilland Aeronautical Technical School Old Boy's Association- Winter Edition 1966 – article on the LSWT Grubb-Parson balance	1966	PF	1
06-2012PB40-79	Correspondence file between James M Monro & Son the DH architects and DH concerning the construction of the LSWT and HST.	1952-53	PF	2
06-2012PB40-80	A Proposal for V/STOL Wind Tunnel with an Open Return Circuit Layout booklet	1963	PF	2
06-2012PB40-81	Proposed Extension to Model Shop plan	1978	PF	2
06-2012PB40-82	Super Sprite Nacelle drawing	1956	PF	1
06-2012PB40-83	Large file of unsorted loose report sheets	Various	PF	3